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BIOLOGICAL NOTES ON THE TERMITES OF THE CANAL ZONE AND ADJOINING PARTS OF THE REPUBLIC OF PANAMA[1]

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INTRODUCTION

The Isthmus of Panama, especially that part of it which now forms the Canal Zone, has been at various times in the past, and is now, one of the great highways of the New World's commerce. Here it is that the Americas and the Old World meet. Despite this fact, little or nothing is known about the majority of the insects that occur there and affect the white man's ability to continue his conquest of the Tropics.

In any new region invaded by the white man, his activities sooner or later result in the overturning of the so-called "balance in nature," which is followed by a readjustment. In the Canal Zone the American régime has begun the agricultural development of the region, which in turn has led to a similar development in the adjoining parts of Panama. Thus decided changes have been wrought. Large areas have been denuded of their original tropical vegetation and have been replaced by cities or towns, by extensive pasture lands, or by agricultural projects of various kinds. Likewise, by the impounding of the waters of the Chagres River to form Gatun Lake and to make the Panama Canal possible, over one-fourth of the total area of the Canal Zone was inundated, killing outright all the vegetation growing on it.

Such procedure has unquestionably brought about radical changes in the fauna of the region, and the insects living there have died out or become scarce; or they have gone to whatever jungles or other untouched areas were left; or they have adapted themselves to the new order of things, increased in numbers, and become insects of economic importance. It is this last course that the termites, "white ants," or, as they are called in Central America, "comejenes," have largely followed. Several species have become important pests of buildings, while other species are, or promise to be, enemies of growing crops. The hardest kinds of woods are riddled by termites (see Pl. 7).

The United States Government in recent years has spent no less than $10,000 in repairing damage caused by termites to the woodwork of the Hotel Tivoli at Ancon, C. Z. The woodwork of this hotel is infested by several species of termites.

[1] Accepted for publication Aug. 11, 1923.

[2] Resigned November 3, 1919. The arrangement of the authors' names is purely alphabetical and denotes neither seniority nor precedence.

Although there are several references in literature to the termites that occur in Panama, in only two cases has definite work dealing with these species been done. Dudley and Beaumont (*6*, *7*, *8*),[3] have contributed three papers on the biology and habits of several of the species found in the Canal Zone and in near-by parts of the Republic of Panama. Banks (*1*) has recently published a taxonomic paper on the species of the same general region based on material collected by Motschulsky, Dudley, Beaumont, Jennings, Busck, and the Hassler Expedition.

It is the purpose of this article to bring together all that is known about the habits and habitats, the biology, and the economic importance of the 21 species of termites that have been recorded from this region. Four of these were new and their habits hitherto unknown.[4] This paper is based largely on the material collected by Mr. Dietz and notes that were made by him at the time the material was collected. Doctor Snyder[5] (*21*) has identified and described the material and both authors have helped to interpret the field notes. Their work has been supplemented by material for identification and notes from various sources that have been sent to Doctor Snyder from time to time.[6] Credit for such notes and material is given in the text.

All of the material collected was given an accession number in the field and all notes were taken under the same number. The notes and observations recorded were based on collected specimens, and, in the case of the photographs of the nests, these were accompanied by specimens taken from the nest and numbered with the same number that was given to the negative. That this is an important procedure is shown in the case of the work done by Dudley and Beaumont. The classification of the termites in their day had not reached the plane on which it is to-day, and Banks (*1*), in working over their material, found that, instead of one species, they had at least two or more in the genera Nasutitermes and Amitermes. Therefore, although the present writers suppose that the common species in the genus "Eutermes" Fritz Müller (l. s.) with which Dudley and Beaumont worked and which they later designated as "*Eutermes*" (*Termes*) *morio* Latreille was most probably *Nasutitermes cornigera* Motschulsky, unfortunately they can not be certain of the fact, nor does any means remain to-day by which the question can be definitely settled. The identity of other termites described by Dudley and Beaumont is also in doubt.

Twenty-one species of termites have been recorded from the Canal Zone and adjacent regions in Panama and specimens are in hand of all these species. Fifteen of these species occur on the Pacific slope and 10 of them on the Atlantic slope, but of these 10 only 8 are from both slopes. Hardly any collecting, however, has been done on the Atlantic slope. In Table I these termites are given in their proper systematic position and their present known distribution in the Canal Zone and near-by parts of Panama is shown. The difference in the distribution may be at least partly due to the 33⅓ per cent greater rainfall on the Atlantic slope than on the Pacific. Dr. David Fairchild (*9*) states that the rainfall at Chagres on the Atlantic slope is nearly double that on the heights of Balboa on the Pacific side.

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[3] Reference is made by number (italic) to "Literature cited," pp. 301–302.

[4] This article was written in May, 1921. Since then other species of termites have been found in Panama, descriptions of some of which have been published.

[5] SNYDER, THOMAS ELLIOTT. DESCRIPTIONS OF NEW SPECIES AND HITHERTO UNKNOWN CASTES OF TERMITES FROM AMERICA AND HAWAII. *In* Proc. U. S. Nat. Mus., v. 64, not yet published.

[6] Special mention should be made of the assistance generously given Mr. Dietz by James Zetek, formerly entomologist of the Canal Zone. Ignacio Molino assisted in collecting specimens. Since Mr. Dietz left Panama, Messrs. Zetek and Molino have continued to cooperate.

TABLE I.—*Distribution of the termites of Panama*

Species.	Locality.	Atlantic slope.	Pacific slope.	Both slopes.
Family Kalotermitidae:				
Kalotermes marginipennis Latreille.	Gamboa, Canal Zone	×		
	Taboga Island, Republic of Panama.		×	×
Neotermes holmgreni Banks.	Paraiso, Canal Zone		×	
	Tabernilla, Canal Zone	×		×
	Taboga Island, Republic of Panama.		×	
	Trinidad River, Republic of Panama.	×		
Cryptotermes brevicollis Banks.	(?)			
Cryptotermes dudleyi Banks.	(?)			
Cryptotermes longicollis Banks.	(?)			
Cryptotermes thompsonae Snyder.	Ancon, Canal Zone		×	
Family Termitidae:				
Coptotermes niger Snyder.	Ancon, Canal Zone		×	
	Bohio, Canal Zone	×		×
	Frijoles, Canal Zone	×		
	Gamboa, Canal Zone	×		
	Gold Hill, Canal Zone	[a]	×	
	Juan Mina, Canal Zone	×		
	Panama City, Republic of Panama.		×	
Amitermes medius Banks.	Las Sabanas (Panama City), Republic of Panama.	[a]	×	
	Taboga Island, Republic of Panama.		×	
Amitermes beaumonti Banks.	Juan Mina, Canal Zone	×		
	Trinidad River, Republic of Panama.	×		
Cornitermes acignathus Silvestri.	Cabima, Republic of Panama.		×	
Armitermes armigera Motschulsky.	Paraiso, Canal Zone		×	
Nasutitermes cornigera Motschulsky.	Ancon, Canal Zone		×	
	Balboa, Canal Zone		×	
	Bracho, Canal Zone	×		
	Chagres River	×		
	Colon, Republic of Panama	×		×
	Gamboa, Canal Zone	×		
	Gatun Lake, Canal Zone	×		
	Juan Mina, Canal Zone	×		
	Las Cascadas, Canal Zone	×		

[a] Divide (Pacific slope).

TABLE I.—*Distribution of the termites of Panama*—Continued

Species.	Locality.	Atlantic slope.	Pacific slope.	Both slopes.
Family Termitidae—Con.				
Nasutitermes cornigera Motschulsky.	Las Sabanas, Republic of Panama.	.....	×	
	Pacora, Republic of Panama.	.....	×	
	Panama City, Republic of Panama.	.....	×	×
	Summit, Canal Zone.....	[a]	×	
	Trinidad River, Republic of Panama.	×	.....	
Nasutitermes pilifrons Holmgren.	Cabima, Republic of Panama.	.....	×	
	Paraiso, Canal Zone.....	.....	×	×
	Trinidad River, Republic of Panama.	×	.....	
Nasutitermes ephratae Holmgren.	Ancon, Canal Zone.....	.....	×	
	Cabima, Republic of Panama.	.....	×	
	Frijoles, Canal Zone.....	×	.....	×
	Las Cascadas, Canal Zone...	×	.....	
Nasutitermes guayanae Holmg. var. *columbicus* Holmgren.	Frijoles, Canal Zone.....	×	.....	
	Las Cascadas, Canal Zone...	×	.....	×
	Las Sabanas, Republic of Panama.	.....	×	
Anoplotermes gracilis Snyder.	Ancon, Canal Zone.....	.....	×	.....
	Las Sabanas, Republic of Panama.	.....	×	.....
	Panama City, Republic of Panama.	.....	×	.....
Eutermes debilis Heer.	(?).....	.....	.....	.....
Eutermes exiguus Hagen.	Las Sabanas, Republic of Panama.	.....	×	.....
Mirotermes hispaniolae Banks.	(?).....	.....	.....	.....
Leucotermes tenuis Hagen.	Ancon, Canal Zone.....	.....	×	
	Cabima, Republic of Panama.	.....	×	
	Frijoles, Canal Zone.....	×	.....	×
	Panama City, Republic of Panama.	.....	×	
Leucotermes convexinotatus Snyder.	Colon, Republic of Panama.	×	.....	
	Las Sabanas, Republic of Panama.	.....	×	
	Matias Hernandez, Republic of Panama.	.....	×	
	Obispo.....	×	.....	×
	Panama City, Republic of Panama.	.....	×	
	Summit, Canal Zone.....	.....	×	

[a] Divide (Pacific slope).

FAMILY KALOTERMITIDAE

Certain members of the family Kalotermitidae, such as species of Kalotermes and Cryptotermes, are very destructive to the interior woodwork of buildings and to furniture. They differ from other termites in that they attack dry wood—if any wood in a region where the relative humidity never goes below 70 per cent can become dry—and do not need a constant resource of moisture in order to continue their work. Hence all that is necessary for the beginning of an infestation is a crevice in woodwork or furniture where a fertilized female can secrete herself. Dudley and Beaumont (*6*, *7*, *8*), taking advantage of this fact, used white ash blocks of dry wood shown in Plate 6, A, for making observations on *Kalotermes marginipennis* Latreille.

Six species of termites in this family occur in Panama. Much trouble is experienced in obtaining forms for specific determination, since the owners of valuable infested furniture are usually adverse to tearing it apart in order to obtain the soldier caste. It is therefore necessary to watch for emergence of winged forms.

Usually the furniture or woodwork is infested with species of this family before their presence is even suspected. In their work these insects, although they come very near to the surface of the wood, do not break through except at a very few places and then usually at an edge or corner of the wood. The holes that are made are only large enough to allow for the casting out of the characteristically sculptured or impressed pellets. The presence of these insects is often indicated by the small piles of pellets beneath infested wood. Likewise, through the sculpturing of the surface of these pellets, which is due to the impression imparted to them in the lower portion of the alimentary tract of the insects, it is possible to identify the genus of the insects excreting them (Pl. 8, B, C).

The following six species of this family have been recorded from the Canal Zone and Panama: *Kalotermes marginipennis*, *Neotermes holmgreni*, *Cryptotermes brevicollis*, *C. dudleyi*, *C. longicollis*, and *C. thompsonae*.

Dudley and Beaumont (*6*, *7*, *8*) first called attention to the destructiveness of termites of this family in Panama and stated that a first-class coach belonging to the Panama Railroad became so badly riddled by *Kalotermes marginipennis* as to be absolutely worthless. Beaumont also found the nymphs and soldiers of *Cryptotermes longicollis* working in a window sill in Panama.

KALOTERMES MARGINIPENNIS

This destructive termite occurs in both Central and North America. It not only injures the woodwork of buildings and other structures but attacks timber as well. The specimens from Panama differ somewhat from those in Texas but are apparently of the same species.

SWARMING[7]

August Busck collected winged adults of *Kalotermes marginipennis* Latreille at trap lights on June 9, 10, and 13, 1911, at Taboga Island, Republic of Panama. At Gamboa, Canal Zone, on May 14, 1919, winged adults were obtained by Mr. Dietz.

[7] This so-called swarming is the colonizing flight of the sexual adults.

NEOTERMES HOLMGRENI

The winged adults of *Neotermes holmgreni* were collected by August Busck on May 7 and June 13, 1911, at Trinidad River, Republic of Panama. Mr. Busck also has specimens from Taboga Island collected on the last-mentioned date. The other stages of this species have not as yet been collected nor is its economic status in Panama known.

CRYPTOTERMES THOMPSONAE

Winged adults of *Cryptotermes thompsonae* were collected in Mr. Dietz's room at Ancon, Canal Zone, on May 7, 9, 11, and 16, 1919. On these days not more than six specimens were seen at any time. The emergence took place in the late afternoon, never earlier than 4 o'clock, and always following a rain either earlier the same afternoon or during the preceding night.

On June 21, 1921, J. Zetek and I. Molino collected nymphs, soldiers and deälated adults, both males and females, of *Cryptotermes thompsonae* from the dry oak baseboard of a revolving bookcase in a room in the Health Laboratory at Ancon, Canal Zone. These termites were first noted through the characteristic frass on the floor. The board was removed and on its upper surface it was found that in places only the thin coat of varnish remained, the wood being all destroyed. There were several large areas, longitudinal, i. e., parallel in a general way to the grain, and, opening into these, small round burrows. (Pl. 8, A.) Soldiers were very few. When the galleries were opened up the soldiers did not assume a vicious attitude; they merely held their mandibles open. Nymphs of the sexual forms were very much more abundant. Five deälated adults were also present, both sexes being included.

The time of the swarming of *Cryptotermes brevicollis*, *C. longicollis*, and *C. dudleyi* is not known.

Just why the termites of the family Kalotermitidae (at least the species upon which we have data) should swarm in this region during the early part of the rainy season (in May and June) is not known, for they attack dry wood (or at least comparatively dry wood for a region like the Isthmus of Panama), and, as has been pointed out above, they are not dependent on a source of moisture in order to continue their work. Probably, however, moisture in wood creates a condition favorable for beginning excavations.

In the case of species of the family Termitidae Banks, some species of which build conspicuous "nests" or termitaria, the absolute necessity for swarming at this time will be pointed out later.

There are records of injury to timber by other species of the family Kalotermitidae the specific identity of which it has been impossible to establish.

In June, 1914, the Western Electric Co. of New York sent nymphs of a species in the family Kalotermitidae to the Bureau of Entomology, United States Department of Agriculture, for identification. These were taken from a bookcase in the National Palace in Panama City.

On November 11, 1918, Mr. Dietz collected nymphs of a species of the family Kalotermitidae which were tunnelling a bureau drawer in the Hotel Tivoli at Ancon, Canal Zone. This drawer was made of oak veneered with mahogany and both kinds of wood were badly riddled by the insects.

At Quarry Heights, Canal Zone, on April 16, 1919, a species of Cryptotermes was found tunnelling a piano which had been brought to Panama by the French when they attempted to dig a canal across the Isthmus. This instrument was made of ebony (?) and one side of it was so badly damaged that it was a mere shell and in many places could have been easily broken through with a slight pressure of the fingers. It was possible to collect only pellets of excrement of this termite.

FAMILY TERMITIDAE

Fifteen species, or the great majority of the recorded termites of Panama, belong to the family Termitidae. These are *Coptotermes niger*, *Cornitermes acignathus*, *Armitermes armigera*, *Mirotermes hispaniolae*, *Leucotermes tenuis*, *L. convexinotatus*, *Eutermes debilis*, *E. exiguus*, *Amitermes beaumonti*, *A. medius*, *Nasutitermes cornigera*, *N. ephratae*, *N. guayanae* var. *columbicus*, *N. pilifrons*, and *Anoplotermes gracilis*. Some of these termites, namely, *C. acignathus*, *A. armigera*, *M. hispaniolae*, and *N. pilifrons*, were not collected during 1918 and 1919 and little seems to be known about their habits, habitats, and potential economic importance.

Considerable information regarding the other species, with the exception of *Amitermes beaumonti*, has been obtained and is of interest either because of the actual or potential economic importance of the particular species or because of its habits, nests, or abundance.

Much of the damage to the woodwork of furniture, buildings, and other structures, such as railroad rolling stock, which has occurred at Panama has been caused by species in the family Termitidae. However, in the family Kalotermitidae species of Cryptotermes are undoubtedly injurious.

COPTOTERMES NIGER

Members of the genus Coptotermes are regarded as among the most destructive termites to timber. In Hawaii, the species *C. intrudens* Oshima (*17*) was thought by Dr. R. C. L. Perkins to have been introduced from the Philippines in army cots stored on one of the docks at Honolulu for a period some years ago[8] and does an enormous annual damage to buildings (*18*). *C. marabitanus* Hagen is a common species in South America. In Australia, *C. lacteus* Froggatt (*11*, *12*, *13*, *14*) is the commonest destructive termite in the vicinity of Sydney, New South Wales, and is especially injurious to the woodwork of buildings.

Although *Coptotermes niger* was collected by both Dudley and Beaumont, there are no published records regarding its economic status in Panama. Mr. Dietz collected this species at both Ancon and Gamboa, Canal Zone, but in neither instance was it considered of economic importance. Nevertheless, it is a species that will bear close watching in the future.

At Gold Hill, in 1916, workers of this termite perforated the lead sheathing of an underground cable, as also the tarred parcelling (Pl. 6, B). Specimens of workers and soldiers were received from the Central and South American Telegraph Co. of New York.

At Ancon on April 15, 1919, workers were found tunnelling a live "copaiferous" tree. The greater part of the nest was through the

[8] Statement in letter of D. T. Fullaway to T. E. Snyder, dated December 29, 1919.

heartwood of the tree with portions of it coming to the surface at various places where areas had apparently died following some external injuries. In such cases the tunnels were brought through the somewhat hardened gum of the tree, which seemed to have been mixed with earth and wood particles excreted by the workers. The outer surface of the entire area was also covered with the same material.

The rainy season of the year 1919 in the Canal Zone began on April 14 and the following day when the nest was found the median line of every tunnel that touched and paralleled the surface was open. In these openings the soldiers had assembled with their mandibles and antennæ directed outward and projecting slightly above the surface. When Mr. Dietz passed his finger or a camel's-hair brush lightly over these openings, the soldiers fairly jumped at them and quickly and viciously took hold, simultaneously secreting a large globule of a milky white, somewhat viscous fluid. All soldiers that were in the least irritated, although they were not touched, secreted this fluid synchronously with the rest. The source of the fluid is a large frontal gland in the head that opens between the jaws. The purpose of the fluid is a protective one and Dudley and Beaumont have called attention to the fact that it will put an insect enemy of the termites *hors de combat*. An account of the use of such a fluid against ants invading the nest of termites is given under the discussion of *Nasutitermes cornigera*. On the fingers or hands the fluid seems to have no effect, and if it has any distinctive odor this is obscured by the pungent odor characteristic of all termites.

Dr. M. Oshima (17), expert zoologist, Government of Formosa, Japan, has called attention to the fact that this fluid, secreted by a Formosan species of Coptotermes, is able to disintegrate *lime* mortar; the soldier of *C. formosanus* Shiraki attacks the mortar by dissolving the lime with acidulous secretions. No experiments have been made to determine the properties of the fluid in the case of the species on the Isthmus of Panama, i. e., *C. niger*.

Once attached to an object, so tenaciously do the soldiers of this species cling that, even if their bodies are torn off, the jaws will not release their hold.

Why the tunnels of this particular nest were open was not definitely determined. Some writers have called attention to similar action on the part of other species at swarming time, the purpose of the soldiers lining the openings of the tunnels being to prevent insect enemies, particularly ants, from raiding the nest. Restricted diggings into parts of this nest, however, failed to disclose any winged forms, and although it was watched daily for more than two weeks, no winged forms were found emerging. At the end of that time all the tunnels were again closed.

The second collection of this species was made at Gamboa on May 14, 1919, following a typical tropical downpour of rain, during the close of which a heavy swarming of *Nasutitermes cornigera* took place. The nest of the Coptotermes in this case was in an old post which was badly riddled. On top of the post, and in several crevices leading down into it, dead and injured deälated adults of *N. cornigera* were found. Apparently these had tried to invade the post to establish new nests and had been killed by the Coptotermes soldiers which were on guard just beneath the surface. These soldiers were very nervous and immediately began secreting considerable quantities of the milky white fluid when their nest was disturbed during the collection of specimens.

On June 16, 1921, Messrs. Zetek and Molino collected soldiers of *Coptotermes niger* from a small hole in an avocado tree trunk at Frijoles, Canal Zone. The wood inside the trunk was honeycombed by these termites. Only soldiers were obtained, although the hole was well explored.

In another tree on the same day workers and soldiers of this termite were found at Frijoles, Canal Zone. The base of the tree was rotted and honeycombed. A soldier of *Leucotermes tenuis* was present in the wood.

At the same locality, on the same day, still another colony was found in a hole at the base of an avocado tree. The hole was filled in with an earthlike mass as hard as talc stone, riddled and inhabited by the termites so that it looked very much like a "nest." (Cavities in trees, poles, etc., are often filled in by termites with a mixture of excreta and earth.) There were also tunnels in the rotted wood.

Coptotermes niger seems to be fond of the gum of "copaiferous trees," and tunnels the tarred parcelling of telephone cables which under ordinary conditions one would suspect of being repellent. In this connection it might be said that the swabbing of building timbers and railroad ties with tar, as is now done in the Canal Zone, has no value in preventing injury by termites and, if the tar coating is of any great thickness, it is even a harmful practice.

The copal tree of tropical Africa is *Trachylobium mossambicense*. From this tree exudes the gum copal in which so many winged fossil termites are found.

SWARMING

Coptotermes niger swarms from April till June.

On April 19, 1919, *Coptotermes niger* swarmed simultaneously with *Nasutitermes cornigera* on the Pacific side of the Canal Zone, between 3 p. m. and dusk following a 12-hour rain. The combined swarm was very large.

On June 18 a much lesser swarming took place, winged adults being collected at Ancon at dusk, following a heavy rain that fell on the preceding day and another rain in the morning of the same day.

That swarming is decidedly influenced by rainfall is shown by the swarming at Juan Mina on the Atlantic side of the divide on May 14, 1919. At noon a very heavy rain began to fall, over an inch falling between that time and 3 p. m. At 2.30 p. m., although it was still raining hard, Mr. Dietz's attention was attracted to the actions of a large number of birds that had collected on the dead trees bordering the Chagres River and repeatedly flew forth from their perches to catch insects. When the rain subsided enough to permit investigation, it was found that the air was full of the large dusky adults of *Coptotermes niger* and *Nasutitermes cornigera* and that not only swallows, but chickens, ants, and spiders were catching these clumsy winged termites. The swarming continued during a drizzling rain throughout the return trip down the Chagres River until about 3.30 p. m., and when a point about a mile above Gamboa was reached, no more adults were seen.

On June 4 James Zetek collected winged adults of this termite at Ancon. The rains had just about begun and it was notable that when the rains were heavy there was no swarming of termites. On June 4 the first long drizzle occurred and at dusk there was a very extensive swarming of termites which lasted about two hours. For a distance of

nearly 3 miles along the streets of Ancon these "Palomitas de San Juan" were everywhere flying aimlessly yet persistently through the air.

On June 28, 1921, Mr. Zetek collected winged adults of *Coptotermes niger* in flight at his home in Panama City. He states:

> There was a heavy downpour at about 11.30 a. m. which lasted till about 2 p. m., with light drizzle after that till about 3 p. m. Thereafter it was very humid and dusky, and the sun hidden by clouds. At exactly 5.30 p. m. on our front porch we saw the first winged termites and then they came in large numbers, flying about aimlessly yet intent upon flying, for as they touched the floor they at once got up again or fluttered around hastily. If a hood was put over them so as to produce darkness, they became very quiet, either entirely still or else walked slowly. We had to adopt this method in order to get good specimens quickly for otherwise it was very difficult to catch them. I was unable to find where they came from. They flew as high as the second story of the house. The flight ended by gradual diminution at about 8 p. m., having made our dinner hasty and nasty. When they alighted on light clothing or on a white face they danced about rapidly, causing much irritation both to skin and temperament. If they alighted on dark clothes or on the skin of a negro they were more quiet and did not move about rapidly. They cause much nervousness in those visited by them, the people becoming very irritable. I am sure the hasty eating, which in unscreened houses necessarily results, reflects on the general health of the victim. Only one species appeared to be involved.

LEUCOTERMES TENUIS

Two new species of Leucotermes have been included under the specific name *tenuis*, one of which, *convexinotatus*, occurs in Panama.[9] *Leucotermes tenuis* is a widely distributed termite and has been found in South America, Central America, and the West Indies. *L. convexinotatus* occurs in Panama and in the West Indies.[9]

Leucotermes tenuis was taken in Panama by Beaumont and *L. convexinotatus* by the Hassler Expedition. The latter is probably the more common species. Both species are found on the Atlantic as well as the Pacific slope. These two termites have apparently the same habits; they attack timber and living vegetation and are found in the outer parts of mound nests of *Amitermes medius*. Both *L. tenuis* and *L. convexinotatus* are of considerable interest from an economic point of view and of great importance in the Canal Zone and Panama, where they do considerable damage both to timber and to living vegetation. These termites have been found in a wide variety of habitats, and are common and destructive species.

Leucotermes tenuis well illustrates what may happen when tropical termites, even though they seem unimportant in their native home, are introduced into a new region where conditions are favorable to their establishment. This has also been shown in the case of *Coptotermes intrudens* Oshima, the history of the introduction of which into Hawaii is not so clear as is that of the introduction of *L. tenuis* into the isolated island of St. Helena. Froggatt (*10*, *11*, and *14*) has given the account of this. In the year 1840 a West Indian slaver was captured by the British warships in the vicinity of St. Helena and towed into the port of Jamestown, where it was allowed to rot. In due season the winged adults of the termites (*L. tenuis*), with which its wooden hull had become infested in the West Indies, swarmed and flew into the town. Conditions being favorable to its development, the species soon established itself in the wooden roofs and other parts of the buildings, necessitating the removal

[9] SNYDER, Thomas E. OP. CIT. Unpublished.

of the infested parts in a short time. It was later estimated that damage amounting to 60,000 pounds sterling to the buildings there had been done by this termite, 30,000 pounds being the amount of damage in Jamestown alone.

The fact that these termites not only tunnel the woodwork of buildings but also attack and tunnel living plants in the field makes the species of great potential economic importance in the Canal Zone and Panama, especially since the agricultural development of the region is now taking place.

Leucotermes tenuis is often closely associated with a species of Nasutitermes in the woodwork of infested buildings in Panama or even as an apparent inquiline in the tunnels of species of Nasutitermes, one such case of this having been found. The instance was brought to the attention of Mr. Dietz by Mr. Zetek, who collected a few soldiers of *L. tenuis* from tunnels of *Nasutitermes cornigera* on coffins infested by that species, which were stored at Ancon Hospital.

Soldiers and workers of *Leucotermes tenuis* were sent to the Bureau of Entomology for identification along with parts of earthlike tunnels from a termite tunnel extending from the baseboard up into a plastered wall to a picture molding in the National Palace, Panama City, R. P., on January 1, 1914, by the Western Electric Co. of New York. This is the first instance brought to the writers' attention of the construction of earthlike shelter tubes by this termite.

Leucotermes tenuis was found tunnelling a living eggplant at Frijoles, Canal Zone, on October 23, 1918.

On May 13, 1919, a nest of this species was found beneath the bark of a rotting log on a vacant lot in Panama City and soldiers and workers as well as the winged adults, ready to swarm, were taken. There was nothing unusual about this nest, which seemed to be a rather small one consisting of not more than several thousand (?) individuals. No earthlike shelter tubes or secreted runways such as are built by members of the genus Nasutitermes were found, the galleries of *Leucotermes tenuis* being tunnelled through the wood. Several species of ants were also found inhabiting the same log in close proximity to the termites and apparently at peace with them or oblivious of their presence. When the log was broken open, however, the ants raided the termite nest, carrying off large numbers of all stages in spite of the resistance of the soldiers, well-armed but too few in numbers to protect their opened nest. The queen of the nest was not found.

On April 28, 1921, J. Zetek and I. Molino collected soldiers of *Leucotermes tenuis* in a rotted piece of log at an avocado plantation at Frijoles, Canal Zone. These were associated with the workers, soldiers, nymphs, and winged adults (which were ready to fly) of the termite *Nasutitermes guayanae*, var. *columbicus*.

Messrs. Zetek and Molino found a soldier of this termite in the wood at the base of an avocado tree at Frijoles, Canal Zone, on June 16, 1921. In this case *Leucotermes tenuis* was associated with *Coptotermes niger*, workers and soldiers. The base of the tree was rotted and honeycombed.

SWARMING

The swarming of *Leucotermes tenuis* takes place during the early part of the rainy season. Winged adults were caught flying at Cabima on May 19, 1911, by August Busck. Winged adults were collected on May

15, 1919, beneath the bark in an old log at Panama City, Republic of Panama, by Dietz and Zetek.

LEUCOTERMES CONVEXINOTATUS

The other species, *Leucotermes convexinotatus*, was first found tunnelling the woodwork of buildings in Colon by engineers of the Western Electric Co. in 1914.

At Colon, Republic of Panama, this termite was taken from tunnels in sweet potatoes on October 25, 1918, the injury to this host superficially resembling that of the sweet-potato weevil, *Cylas formicarius* Fabricius. Banana stumps were found riddled by it at Matias Hernandez, Republic of Panama, on October 29, 1918. In the Las Sabanas region of Panama *convexinotatus* has been found living as an inquiline or "social parasite" (?) (*22*) in the outer parts of all the large nests of *Amitermes medius* that were opened.

On February 11, 1920, Mr. Zetek found specimens of workers and soldiers of *Leucotermes convexinotatus* at Panama City infesting young avocado trees received from Cuba and planted the day after receipt. Injury was first noted a month or so after planting. It was thought that the termites came with the ball of dirt which was around the plants, since nests were found in it. Species of Leucotermes (*L. convexinotatus* and *L. cardini* Snyder) occur in Cuba, but the specimens were not necessarily imported, since these termites are injurious species in Panama.

L. convexinotatus was found by Zetek on February 11, 1921, at El Retiro, Rio Abaja section, Las Sabanas, near Panama City, mining sugar cane.

On May 4, 1921, Messrs. Zetek and Molino opened a mound nest of *Amitermes medius* at Las Sabanas, the galleries of which were crowded with winged forms of *Leucotermes convexinotatus*. Soldiers and workers of *L. convexinotatus* were also present and seemed to dominate the upper and middle portions of this nest of Amitermes. Apparently either species of Leucotermes lives peacefully with Amitermes until human beings disturb the nest, upon which the two species engage in combat.

On May 13, 1921, Messrs. Zetek and Molino found workers and soldiers of *L. convexinotatus* in the roots of a dying young citrus tree at the Summit, Canal Zone, plantation. The termites were very abundant in the field and dead wood lay about freely.

SWARMING

Leucotermes convexinotatus apparently swarms during the same season as does *L. tenuis*. Immature winged adults were collected at Colon, Republic of Panama, on April 11, 1914, in the woodwork of the cable office.

On May 4, 1921, winged adults were found in an Amitermes nest at Las Sabanas, as described above. These adults were mature and ready to swarm. On May 3 and 4, 1921, Mr. Zetek collected winged adults of this species swarming at Panama City in the dining room of a dwelling house. These were abundant and were flying with adults of *Anoplotermes gracilis*.

Winged termites of *L. convexinotatus* were collected in Mr. Zetek's dining room in Panama City, around a 60-watt electric light, at about

7 p. m. on May 24, 1921. They were very abundant. It was raining slightly about this time. A light breeze made with a fan quickly dispersed them.

EUTERMES DEBILIS

This species is one of potential economic importance and of scientific interest because of its habits and history. Heer's type is a fossilized form in gum copal in the Zurich Museum. Unfortunately neither the age nor the origin of this copal is given, though it is unquestionably of tropical American origin. It is probable, since it has been found in copal, that the species is an old one. Hagen (*15*) also examined another specimen in copal (from the Königsberg Museum, Cabinet No. 559) in the same piece of which was a winged specimen of the Antillean species *Cryptotermes brevis* Walker.

Von Moritz collected *Eutermes debilis* in Porto Rico and Burmeister obtained it in Brazil. Hagen described the soldier from specimens from Panama. Hence it is evident that *E. debilis* is widely distributed in the American Tropics.

The exact localities in which this termite has been found in Panama are not known. A first-form queen in the Beaumont collection from Panama measures 24 mm. in length.

EUTERMES EXIGUUS

On May 11, 1921, at Las Sabanas, Messrs. Zetek and Molino found winged adults, soldiers, and workers of *Eutermes exiguus* in a mound nest of *Amitermes medius;* workers of Anoplotermes also occurred in this nest.

AMITERMES BEAUMONTI

No nests of *Amitermes beaumonti* were seen by Mr. Dietz. Soldiers of this species were found in the Beaumont collection and the species was named in his honor. It may be that the large mound nests to which Dudley and Beaumont (*8*) refer under the name of *Termes columnar* are those either of this species or a species of Anoplotermes. These nests were 5 feet in diameter and nearly 4 feet high. No termite nests approaching this size have been found in the Canal Zone or Panama by either Mr. Dietz or Mr. Zetek, who has traveled extensively throughout the entire region.

SWARMING

What appear to be the winged adults of this species were taken by August Busck at Trinidad River, Panama, on May 5, 1911, and by Dietz and Zetek at Juan Mina, May 14, 1919. The adults collected by Dietz and Zetek occurred sparingly among the enormous swarms of the larger, black, but otherwise superficially similar adults of *Nasutitermes cornigera.*

AMITERMES MEDIUS

This species is of interest because it is a close relative of *Amitermes meridionalis* Froggatt which builds the curiously oriented "meridional" or "magnetic" nests in Australia recently discussed by Mjöberg (*16*) and because it also builds a very conspicuous nest. These nests or termitaria are hard, more or less hemispherical, reddish or brownish earth mounds

(Pl. 4) of varying size, the larger ones often 2½ feet in diameter and 2 feet in height. They are usually built around and over low shrubbery, logs, or stumps, or in some instances around the bases of fence posts. On the flat, treeless pasture lands of the Sabanas region a few miles from Panama City, these nests are a common sight and remind one of the first account of mound-building termites, written by Smeathman (*20*), in which he pictures a wild bull surveying the surrounding country from the top of the nest of an African termite.

These nests are built from particles of earth which, having passed through the alimentary tract of the workers, are cemented together. The enveloping walls are constructed of surface soil, not of soil mined from below. Because of their shape and texture these nests are almost impervious to water; some that were examined after a heavy shower showed that only the outer wall had been penetrated by the rain. Because of their shape and internal structure (Pl. 4, B; Pl. 5) these nests are so solid that one can jump up and down on them without making the least impression, and when one attempts to open them with a machete it glances off as it would if one were trying to chop a stone in half.

Froggatt (13) records that the earthlike material from the nests of certain mound-building species in Ceylon is so fine that it is used by the native jewellers to polish gems. Several writers state that the material from similar nests is employed by the natives in parts of Africa for the floors of their huts and "J. M. C." (*2*) says that in Australia these termite mounds are used in making tennis courts. There is little question that the earth-material nests of *Amitermes medius* would make as good courts as cement. In no instance, however, have the natives of Panama been found using these mound nests.

From all records available this species seems to be confined to the Pacific side of the Canal Zone and to the Republic of Panama. In all the nests that have been opened no queens have been found; they are probably in the deeper underground parts. Considering the size of the nests, the number of inhabitants seems much smaller than in the case of species of the genus Nasutitermes.

On the afternoon of May 4, 1921, Messrs. Zetek and Molino broke open a nest in the vicinity of Las Sabanas (near Panama City). This mound nest was about 2 feet high and quite hard, a geological pick being required to open it. The galleries were filled to overcrowding with winged forms. The winged adults were always congregated in the galleries and cells lined with white (Pl. 5, B). This white lining is found in nests of *Leucotermes tenuis*, according to Silvestri (*19, p. 112*). In the upper and middle parts of this nest the lighter colored form with narrow wings (*convexinotatus*) predominated. In the whole nest this was the prevailing form. At the base of the nest were obtained smaller numbers of the adult with darker and wider wings (*Amitermes medius*). The soldiers tightly grasped the forceps extended to them.

Soldiers of *Leucotermes convexinotatus* were also present in the galleries of this mound nest. Soldiers of *Amitermes medius* and *L. convexinotatus* were found with mandibles locked about each other.

SWARMING

May 4, 1921, at Las Sabanas, was cloudy, and a light rain fell all the time during which the nest was being examined. The winged adults began to emerge at 3 p. m. As the nest was broken up winged adults flew out in clouds.

On May 11, 1921, Messrs. Zetek and Molino opened up a nest of *Amitermes medius* at Las Sabanas, Panama City. Winged adults as well as workers and soldiers of this species occurred in this nest and also workers and soldiers of *Leucotermes convexinotatus*. The small white forms (possibly workers or the young of *L. convexinotatus*) were in cells lined with a whitish, granular substance. The winged forms were abundant and flew about as soon as the nest was opened. These nests were very hard.

Another nest of the same kind was found containing winged adults, workers, and soldiers of *Amitermes medius*. The ant (*Pseudomyrma* sp.)[10] in this material was found inside of the termite nest and quite certainly was not accidentally introduced there while the nest was being dug open.

Still another nest with the same general data was found. The thick-set forms (workers of *Amitermes medius*) were very slow in gait.

As has been mentioned before, *Leucotermes tenuis* or *L. convexinotatus* has been found living as a "social parasite" (?) in the outer parts of all the larger nests of *Amitermes medius* that have been opened.

In a large nest on Taboga Island, Republic of Panama, on June 23, 1919, two individuals of a new species of solpugid spider were found. These have been described as *Ammotrecha tabogana* by R. V. Chamberlin (*3*). Solpugids show a predilection for preying upon termites and there is no doubt that this is the significance of the association in this case.

No covered, earthlike runways built by *Amitermes medius* have been discovered. Species of the genus Nasutitermes commonly construct such runways or shelter sheds, on tree trunks, etc. In this respect *A. medius* apparently differs from the species of the genus Nasutitermes.

Drummond (*5*) has advanced the theory that in parts of Africa the termites, especially the ground-inhabiting forms, take the place of earthworms in the "economy of nature." In Panama, however, this theory does not hold, since earthworms are found there.

At the present time *Amitermes medius* is not of economic importance, but it may become so if the lands on which it occurs are ever planted in crops.

NASUTITERMES CORNIGERA

Nasutitermes cornigera is one of the commonest termites of the Canal Zone and adjoining parts of the Republic of Panama. The conspicuous "nigger-head" nests on fence posts, trees, and especially on the large dead trees on Gatun Lake, attract the attention of visitors to these regions and it is about these nests that Collins (*4, p. 207*) has made the following remarks under the heading of "Things not true":

> ***The Sloth*** **pointed out to the tourist as a black thing hanging from a tree is really an ants' nest. The sloth does hang from a tree, but not alongside the railroad tracks or highways.**

A typical termitarium of this species consists of a main nest on the tree. From this numerous runways extend which traverse the trunks of trees, posts, or the sides of buildings, terminating in the ground. These carton tree nests are often called "nigger heads" because of their shape. These nests may be a considerable distance, as much as several hundred feet, away from the main nest, and are often connected with other carton nests by the characteristic runways. These "nigger-head" nests

[10] Determined by W. M. Mann, Bureau of Entomology, United States Department of Agriculture, who states that its presence was probably accidental.

and runways are shown in Plates 1 and 2. The nests are generally more or less ovoid in shape, the largest one found being 1½ feet long by 1 foot in diameter.

The nest and runways are made of a sort of papier-mâché consisting of finely digested wood, earth, and other substances that have passed through the alimentary tracts of the workers and are cemented into position as they are excreted. The nests and runways are quite tough and are practically waterproof. When either is broken the characteristic brown-headed, long-nosed nasuti (soldiers) and the lighter colored workers rush forth to repair the damage. The carton nests, however, are not always built, nor does the species always reach its feeding grounds by means of external runways, for in Panama City this species has been found tunnelling the heartwood of trees.

Nasutitermes cornigera and *N. ephratae* are of the greatest economic importance in this region, for they do not confine their attacks to trees, posts, and stumps out of doors, but are especially destructive to furniture and the woodwork of buildings. Access to a building is gained from a parent out-of-door nest by means of the runways built up over walls or up the supports on which the building rests; in fact, there are few wooden houses or buildings in the Canal Zone that do not show traces of such tunnels. Once in the building, carton nests such as are shown in Plate 3, A, B, are constructed between the walls or on the joists and studdings.

There are records of this species working in wood at the Washington Hotel, Colon, Republic of Panama, in tunnels on a storehouse at Gamboa, Canal Zone, and in a newel post at the Hotel Tivoli, Ancon, Canal Zone. At Ancon Hospital, *N. cornigera* tunnelled coffins made of poplar wood and veneered with oak, stored under the building; 7 out of 19 coffins were infested, 3 being badly damaged.

N. cornigera has also been found at Balboa, Canal Zone, tunnelling pieces of dead tree limbs on which orchids were growing. This indicates a method by which the species might be distributed in the absence of strict plant quarantine regulations; in fact, *Nasutitermes morio* Latr. has been intercepted coming into the United States from Trinidad in just such a manner, by inspectors of the Federal Horticultural Board at New York City.

On July 12, 1920, Zetek and Molino collected workers and nasuti of *Nasutitermes cornigera* in covered runways on cacao trees at the Las Cascades Cacao Plantation, Canal Zone. There was hardly a cacao tree on the plantation which did not have runways of these termites on the trunk. The manager stated that chickens eat the termites and that he expected to use them as controls. An ant, *Azteca* sp.,[11] was present with the termites.

On January 31, 1920, Mr. Zetek found workers and nasuti of *Nasutitermes cornigera* on another cacao plantation at Las Cascades. In this lot were a large number of young reproductive types which might have been of the second form, with short wing pads and slight grayish pigment on the wing pads and other parts of the body. The eyes were pinkish. If of this type, it is believed this is the first record of the occurrence of second-form, reproductive individuals in the genus Nasutitermes. An ant, *Dolichoderus* (*Inonacis*) *bispinosus* Oliv.[11] was present with the termites.

[11] Determined by W. M. Mann of the Bureau of Entomology.

Two large, black, ovoidal nests of *Nasutitermes cornigera* were found on tree trunks at Las Sabanas, Panama City, on May 4, 1921, by Messrs. Zetek and Molino. Workers, nasuti, and young nymphs, but no winged forms, were in the nests. The white individuals (workers or nymphs?) exuded a white gummy fluid. First-form queens were found in six tree nests on "soursop" trees (*Annona muricata*), at Juan Mina, Canal Zone, on February 18 to 19, 1921; these queens were enlarged, egg-laying, reproductive forms.

There were 17 queens in one nest on a tree. The termite burrows are about one-half to 1 inch broad and about three-eighths to one-half inch thick. The nest was about 2 feet high and 1 foot in diameter. All termites collected on "soursop" trees were of this sort.

The members of the genus Nasutitermes, and *N. cornigera* in particular, are known as "duck ants" by the West Indian negroes. These negroes and the natives of the region often open the carton nests and feed the inhabitants to chickens and ducks, which seem to relish them in spite of the characteristic pungent termite odor. So pronounced is this odor in all the species that have been collected in this region that it will remain on one's hands several days in spite of numerous washings with soap and water or with ethyl alcohol.

All of the typical "nigger-head" nests that have been examined on both the Atlantic and Pacific sides of the Canal Zone and Panama have been those of this species. A nest about 18 inches wide was dissected at Las Sabanas on May 4, 1921, by Zetek and Molino. The nest was on a tree and was black in color, as is usual in the case of this termite. Soldiers and workers were present, but no winged adults were in the nest at this time of the year.

In one case at Bracho, Canal Zone, on July 10, 1918, 15 queens were obtained from a large ovoid nest 1½ feet long and 1 foot in diameter at its widest part. In this nest 2 queens were usually found in each "queen chamber," although Dudley and Beaumont record having taken 10 queens from a "queen chamber" of what may have been this species. The queens were all rather small, measuring less than 30 mm. (Pl. 3, C) and were all first-form or "true" queens, i. e., developed from dealated fertilized females.

Most of the queens of this and other species of Nasutitermes that have been obtained are of this type. In two other, though somewhat smaller nests, at the same place and on the same day, 3 and 4 queens were obtained, respectively.

SWARMING

The swarming of this species takes place from April till June, the earliest record having been that by Jennings on April 8, 1910, at Las Cascadas, Canal Zone. August Busck collected winged adults at Trinidad River on May 5, 1911. On the Pacific side of the Canal Zone and Panama, the main swarming of *N. cornigera* took place between 3 p. m., and dusk on April 19, 1919, following a 12-hour rain; at the same time and place *Coptotermes niger* swarmed. The large, black, winged adults of these two termites are superficially very difficult to separate and were naturally confused in the field, being given the same numbers when found swarming together.

On May 14, 1919, winged adults were observed at Gamboa at 5 p. m., 45 minutes after the last specimens of this termite and *Coptotermes niger* had been noted swarming over the Chagres River. When the swarm

did appear at Gamboa the rain had ceased and the winged adults came in ever-increasing numbers from the woods north of the town and drifted out over the Canal, where large numbers perished. This flight was still in progress when observations were discontinued at 6 p. m. Since there was no rain at the time on the Pacific side of the Divide, no termites were found swarming at Ancon or Panama City.

In a region like the Canal Zone and the adjoining parts of the Republic of Panama, where there is such a decided difference, even within short distances, not only in the quantity of rainfall, but also in the time during which it falls, one place being deluged and another remaining dry, it is apparent that there will be a considerable range in the time that swarming takes place even in the same species, for it seems that accumulated rainfall is a factor in determining the time that this event occurs. Species like those of Nasutitermes, Amitermes, and Anoplotermes, whose main nests are built in the ground and which require moisture in order to continue their work, must swarm early in the rainy season in order to establish themselves thoroughly, for during the dry season, from the last part of December to the first or middle of April, practically no rain falls over a considerable part of the region and the ground becomes hard, dry, and cracked for several feet down.

The fact that such large numbers of "true" queens have been found in the same carton nest leads to the conclusion that in this species winged individuals are more or less gregarious even after fertilization.

Because of the number of queens that occur, the nests of this species are crowded with workers and soldiers and this seems to be an advantage in keeping out intruders such as the ants in case the nest or runways are damaged. On July 19, 1919, in the Las Sabanas region of Panama the carton nest shown in Plate 2, A, was cut open with a machete to obtain queens. The outer parts of the stump on which this nest was found were inhabited by the termites and the inner parts of it by carpenter ants, *Camponotus abdominalis* Fab., subspecies *stercorarius* Forel.[13] The ants and termites, as has been repeatedly observed, were living in apparent peace, either unaware of the existence of each other or in a state of "armed neutrality." In opening the termite nest with a machete the stump was also split and the termite hordes poured forth only to meet the throngs of furious ants. Each apparently blamed the other for the catastrophe that befell its nest. The ants rushed at the termites with open jaws, closing them and crushing as many as half a dozen at a time. But the taste of termite blood was not pleasant and the ants soon let them fall. The worker termites grasped their enemies by the legs and antennæ while the nasuti with their "beaks" borne aloft and secreting the white, milky fluid from the tips thereof, rushed at the invaders as if to pierce them through. Their favorite point of attack was the abdomen, especially the pedicel of the ants, and here as many as four nasuti were found attached to a single invader by the fluid they had secreted, while half a dozen workers were clinging to its legs and antennæ. Though this fluid seems to have no effect on the skin of man, it apparently paralyzed the ants and numbers of them were seen to curl up, lose their hold on the stump, and fall to the ground helpless. If an ant did succeed in freeing itself from one lot of termites it was soon covered with another and it seemed unable to do anything when these got on its back or on its abdomen. The ants soon became discouraged,

[13] Determined by W. M. Mann of the Bureau of Entomology.

for although they killed hundreds of nasuti and worker termites, they were unable to reduce the numbers that swarmed forth to meet them and so in the course of 20 minutes the fight was over, the ants withdrawing, leaving the termites the victors. These marched up and down the stump and over the ground at its base in never-ending streams, apparently at a loss as to how to repair their completely ruined nest.

NASUTITERMES EPHRATAE

Nasutitermes ephratae, like the preceding species, is of considerable economic importance. At the Hotel Tivoli at Ancon, Canal Zone, its tunnelling in the wood necessitated the removal of over 8,000 square feet of oak flooring. These floors were laid on spruce and yellow pine joists, which, in the presence of the oak, remained free from attack. Out of several hundred joists examined one of oak was found and it was badly riddled.

N. ephratae was also found tunnelling through trunks and their contents and through boots and shoes where these had been left standing undisturbed for a long time. It showed a predilection for the outer surfaces of the last mentioned articles.

Carton nests such as those shown in Plate 3, A, B, were occasionally found on the joists beneath the floors and in one instance a large nest 3 feet high, 2 feet wide, and 6 inches deep was found between the wooden walls of a bathroom. This nest resembled superficially the comb in an old box beehive.

These termites need a source of moisture in order to continue their work, and in buildings of the Canal Zone and Panama they usually find it in the bathrooms, where some parts of the floors are always moist, owing to the general prevalence of shower baths. It is in the vicinity of the bathrooms that these termites are found in the greatest number and the damage is worst. When they gain entrance to a building and become established they do not need access to the ground for a source of water supply, and the removal of the runways leading from the building to the ground does not cause the species to die out.[13]

No out-of-door nests of *Nasutitermes ephratae* had been found until 1921, all the "nigger-head" nests examined being those of *N. cornigera*. In texture and general internal structure the nests and runways of *N. ephratae* are inseparable from those of *N. cornigera*. On February 19, 1921, however, Molino and Zetek found a small nest of *N. ephratae* on a mango tree in an avocado plantation at Frijoles, Canal Zone. This was the only nest seen. Only one large egg-laying queen was present.

SWARMING

In the Tivoli no winged adults were taken in 1919, although careful watch was kept for them from April until the end of July. On May 20, 1911, at Cabima, Panama, Busck took the winged adults at trap lights.

A queen in the Beaumont collection measures 27 mm. in length and 5 mm. in width; the queen is of the first form.

[13] On January 19, 1920, Mr. Zetek collected specimens of workers and nasuti of *Nasutitermes ephratae* injuring a filing case in a building at Ancon, Canal Zone.

NASUTITERMES GUAYANAE VAR. COLUMBICUS

Only one nest of *Nasutitermes guayanae* var. *columbicus* has been found. This was discovered in the Sabanas region, Republic of Panama, on July 19, 1919 (Pl. 2, B). In general the nests are built like those of *N. cornigera*. In texture and internal structure they are inseparable from those of the two preceding species, although in shape they are decidedly different, as is shown in Plate 2, the carton nest being nothing more than a covering of the object to which it is attached and formed of numerous confluent and piled up runways. There is, in other words, no regular exterior separate nest.

On January 31, 1920, Mr. Zetek found specimens of workers and soldiers of *Nasutitermes guayanae* var. *columbicus* on a cacao plantation at Las Cascadas, Canal Zone.

On April 28, 1921, Zetek and Molino collected workers, soldiers, nymphs, and winged adults of *Nasutitermes guayanae* var. *columbicus* in a rotten log on an avocado plantation at Frijoles, Canal Zone. These specimens were collected from tunnels and a semidefinite "nest" on a piece of branch at the base of an avocado tree. There was no well-formed nest and it appeared as if the termites entered from the soil. This semidefinite nest was in a hollow of the branch, about 1 foot long by about 6 inches wide. There were about five tunnels in the branch. The branch was well rotted but still firm. With these were found soldiers of *Leucotermes tenuis*.

On June 16, 1921, Messrs. Zetek and Molino collected workers and nasuti of *Nasutitermes guayanae* var. *columbicus* from covered tunnels on the trunk of an avocado tree at Frijoles, Canal Zone. These tunnels were very close to the hole from which soldiers of *Coptotermes niger* were collected. No nest was present and the tunnels did not communicate with the hole so far as could be determined.

There is no doubt that this species may become as serious a pest as the two preceding ones, for, like them, it not merely builds runways over the surface of the wood but tunnels it as well. In this instance it was apparent that the fence post on which the carton nest occurred was not only being tunnelled from below the ground upward, but also downward from beneath the tin capping with which it was covered.

SWARMING

Winged forms of this species ready for flight were taken at Frijoles, Canal Zone, on April 28, 1921, in a log.

On June 16, 1921, Zetek and Molino collected at Frijoles, Canal Zone, winged adults of *Nasutitermes guayanae* var. *columbicus* with workers and nasuti from a piece of rotten avocado limb on the ground at the base of a tree. The wood was well riddled and there were some covered tunnels on the outside which communicated with the ground. No nest was found. The winged adults were very abundant, being packed in small pockets; when these were opened they began to fly about at once. This was at about 10.30 a. m.

OTHER SPECIES OF NASUTITERMES

One other species of Nasutitermes is recorded from Panama, namely, *N. pilifrons* Holmgren. The specimens were all collected by Busck in 1911 and the determinations were made from winged adults.

The adults of *N. pilifrons* were taken at Trinidad River, Republic of Panama, on May 2; at Cabima, Republic of Panama, on May 20; and at Paraiso, Canal Zone, on April 24.

Dudley and Beaumont (*8*) refer to one of the largest nests of "Milesnasitermes" (a genus without a species, to include soldiers with beaks, i. e., "soldier-nosed-termes") yet found upon the Isthmus. It was in a storehouse, and was 10 feet in height, 2½ feet at its greatest width, and 1½ feet at its greatest depth; its estimated weight was 300 pounds. The wood of the building was badly injured, while galleries ran from this to other buildings. One gallery ran to a chapel and the organ was destroyed.

It would be exceedingly interesting to learn what termite constructed this large nest. Quite possibly it was a species of Armitermes, since this invalid genus "Milesnasitermes" could include species in at least three genera, i. e., Nasutitermes Banks, Constrictotermes Holmgren, and Armitermes Wasmann.

ANOPLOTERMES GRACILIS

Anoplotermes gracilis is a small Central American species of the interesting and peculiar genus Anoplotermes and lacks the soldier caste, as in all species of this genus. No nests of it were found.

Certain species of Anoplotermes construct tall, cylindrical, earthlike mounds in tropical regions. Possibly *A. gracilis* is the termite referred to by Dudley and Beaumont (*8*) as *Termes columnar*, which constructed a nest more than 5 feet in diameter at the base and nearly 4 feet in height at Ceroyal Station of the Panama Railroad.[14] These nests have been discovered only on the Pacific slope.

Anoplotermes fumosus Hagen, of Mexico and Texas, however, does not construct earthlike mounds, at least not in Texas, but lives underground and apparently is a "social parasite," (*22*), being found only with other species of termites and never in separate colonies.

In some species of the genus Anoplotermes the exceptionally long jaws of the winged adult are significant, in view of the absence of the soldier caste. This is especially true in the species *A. fumosus*, which is probably a social parasite and lives in the colonies of other species of termites.

Anoplotermes gracilis will probably not prove to be a termite of great economic importance in the Canal Zone. If it constructs large mound nests, they have not as yet been found, and it is probable that this termite lives underground like its North American relative, *A. fumosus*.

On May 11, 1921, at Las Sabanas, Zetek and Molino found workers of *Anoplotermes* sp. in a nest of *Amitermes medius*. They were not very abundant and were congregated thickly in small, white-lined pockets. Possibly the workers are of this species, which is only known from winged adults. Winged adults, soldiers, and workers of *Eutermes exiguus* also occurred in this nest.

SWARMING

The winged adults of this species were collected around lights in houses in Panama City and Ancon, Canal Zone, on April 19, 1919, the former collection being made by Molino and the latter by Dietz. The time of collection was between 6 and 7.30 p. m. in both cases. It will be noted

[14] Probably Coroxal and nests of *Amitermes medius*.

that this swarming was simultaneous with that of *Nasutitermes cornigera* on the Pacific side of the Canal Zone and followed a heavy 12-hour rain six days after the beginning of the rainy season in this region. The significance of this early swarming in the case of species building all or parts of their nest in the ground is discussed under *Nasutitermes cornigera*. Earlier on the same afternoon (April 19) a large number of winged adults of *A. gracilis* were taken from the outer wall of a wasp's nest cut down from a royal palm tree in front of the Ancon Dispensary. The nest was inhabited by *Polybia occidentalis* Olivier.[15]

On May 3 and 4, 1921, Mr. Zetek collected winged adults of *Anoplotermes gracilis* as they flew into a dining room in Panama City. Mr. Zetek stated that these winged adults are termed "Palomitas de San Juan" by the natives; however, any flying termites which are dark in color are thus termed apparently since both *Nasutitermes cornigera* and *Coptotermes niger* have been so designated. These winged termites are a great nuisance, particularly in dwelling houses. In the Las Sabanas region it is necessary to leave the summer homes for the city because of the immense hordes of these insects, which not only prevent one from eating but also are a disturbance at night.

The winged adults emerge usually toward dusk, as a rule after the first one or two heavy rains of the rainy season. If the afternoon is cloudy, and especially if there is a light drizzle, they emerge as early as 2.30 p. m. They also fly about in the early morning hours.

Unfortunately these observations were based on two species of termites, since the winged adults of *A. gracilis* were in a minority. Most of the flying termites were winged adults of *Leucotermes convexinotatus*.

CONTROL

Different remedies and preventives must be instituted in case of damage by the two groups of termites—namely, those that are subterranean in habit, and those nonsubterranean, living in wood. Nearly all cases of damage to buildings by subterranean termites are due to careless or faulty construction.

SUBTERRANEAN TERMITES

The remedy for and prevention of subterranean termites of the family Termitidae are practically the same—namely, complete insulation or isolation of all untreated wood from the ground. Since subterranean termites always require access to damp earth, when the source of moisture is shut off the insects will not be able to extend their galleries further and will perish. If such termites already in the wood are shut off from the source of supply of moisture in the ground, they will soon perish, since they can not live without moisture. It is not necessary to do anything more, since the insects will die when the infested timbers are disconnected from the earth, and, furthermore, such infested timbers need not be removed or replaced unless seriously weakened structurally.

Where stone, brick, or concrete foundations are not used, all timbers in contact with the ground should be impregnated with coal-tar creosote.

Injury to living vegetation by wood-boring subterranean termites can be prevented by clean cultivation and proper horticultural management.

[15] Determined by S. A. Rohwer, of the Bureau of Entomology, Washington, D. C. Since there were no termite runways on the tree (in fact, no workers have been discovered as yet in Panama, nor has this termite been found building runways such as are built by the members of the genus Nasutitermes), no reason for the association of the termite adults and wasps could be ascertained.

Injury is more common in the new soil of recently cleared woodland containing old decaying stumps, wood, or much leaf mold. It is not desirable to use animal manure where damage by termites is serious.

In the case of species of termites of this family which are not wood-boring but which are subterranean in habit and injure vegetation and build mounds in fields which it is desired to cultivate, their galleries should be fumigated with sulphur or arsenic or a combination of the two. There are several effective machines on the market which generate fumes of these poisons in a brazier and force them into the termite galleries by means of a pump. Another method is to fumigate by termitocid cartridges which generate volatile arsenical combinations that enter the galleries under great pressure. Termites can also be controlled by placing poisoned bait in their burrows or nests or by poisoning the soil with poisonous solutions or salts.

Much injury to living vegetation by either class of subterranean termites can be prevented by clean cultivation.

NONSUBTERRANEAN TERMITES

Termites that do not live in the earth—namely, such species as Kalotermes, Neotermes, and Cryptotermes, can not be combatted as can the subterranean species by shutting them off from their supply of moisture in the soil. They infest even dry wood directly through crevices, cracks, or decayed places and require little moisture. Of course their breeding places in decayed wood should be destroyed. Where these species are abundant, windows and doors in buildings should be screened, especially during the period of swarming or flight. In unscreened buildings the lights should be put out during the swarm. Since species in these genera swarm at night and are attracted to lights in large numbers, the winged adults can be caught by placing under the lights large shallow receptacles full of oil or water.

The unprotected woodwork of buildings should be impregnated with chemical wood preservatives. If a coating of the brown creosote or carbolineum is not suitable in the case of interior woodwork impregnation of the wood with a 6 per cent solution of zinc chlorid or a 1 per cent solution of bichlorid of mercury is recommended. A 2 per cent solution of sodium fluorid is effective, as is also impregnation with chlorinated naphthalene. The best method of treatment when using the soluble wood preservatives is by the "open tank."

Possibly the chlorinated naphthalene is the best treatment for furniture. Wood must be impregnated before it is made up into furniture if it is to be effectively protected; no known solution applied externally is satisfactory.

Much of the damage caused by white ants to furniture and interior woodwork in the Tropics is due to the improper construction of buildings. All wood in contact with the ground should be thoroughly impregnated with coal-tar creosote.

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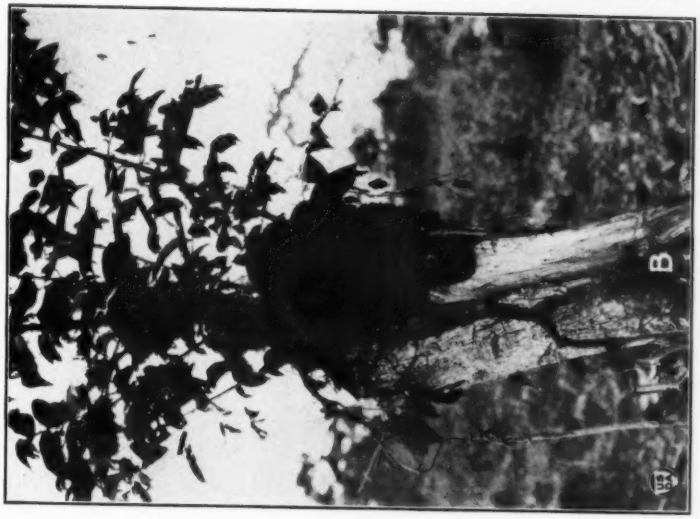
X

PLATE 1

Nasutitermes cornigera

A.—"Nigger-head" tree nest.
B.—"Nigger-head" tree nest.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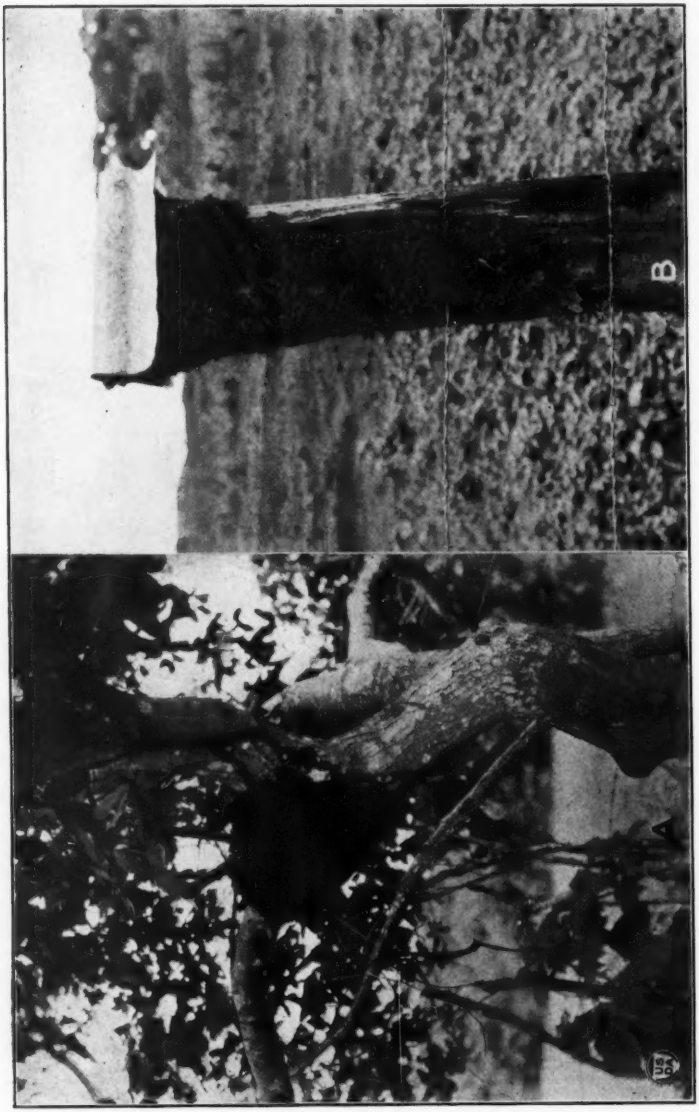
B
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PLATE 2

A.—"Nigger-head" tree nest of *Nasutitermes cornigera*.

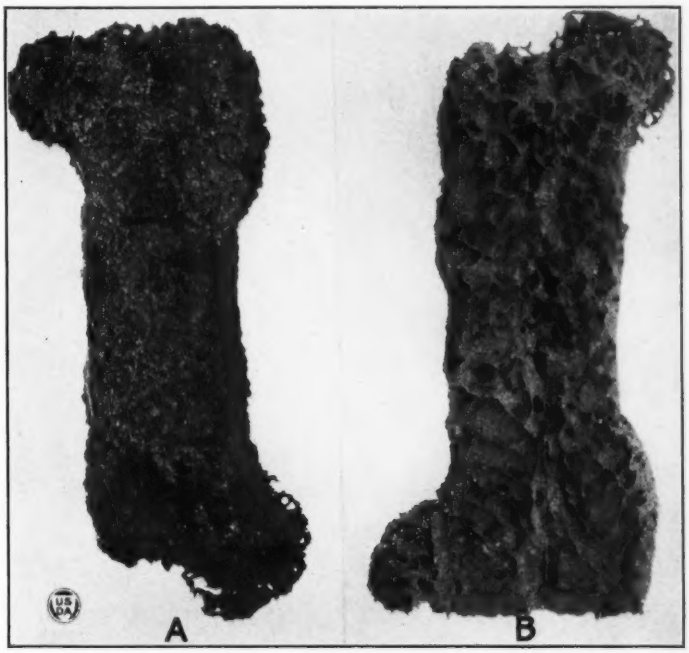
B.—Nest of *Nasutitermes guayanae* var. *columbicus*. Note the tin capping on the top of the post to prevent it from becoming water-soaked through rains. The termites have attacked the post from below and have made use of the capping as a protection against the rain.

PLATE 3

A.—Top view of nest of *Nasutitermes ephratae* taken from a studding in building, Ancon, Canal Zone.

B.—Bottom view of same nest, showing the structure.

C.—First-form queens of *Nasutitermes cornigera*. Enlarged 2 ×.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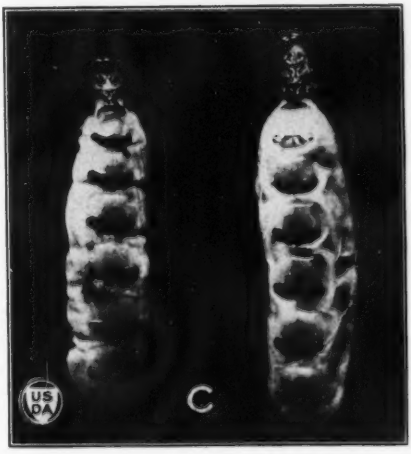
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PLATE 4

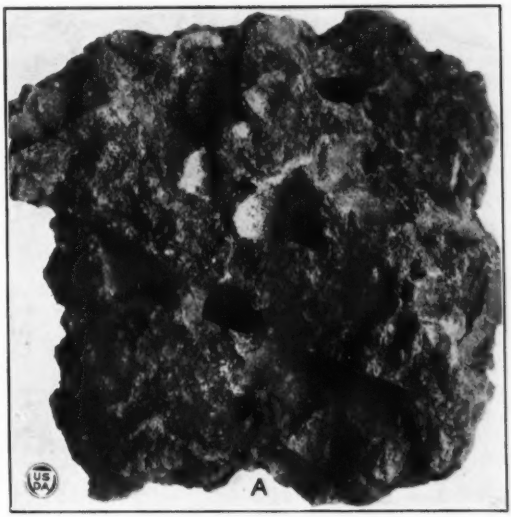
Amitermes medius

A.—Exterior view of a nest.
B.—Longitudinal section of nest, showing its interior structure.

PLATE 5

Amitermes medius

A.—Portion of mound nest showing galleries and cells. Las Sabanas, C. Z.
B.—Portion of the same nest showing galleries and cells. Note the galleries and cells lined with white in which the winged adults were always congregated.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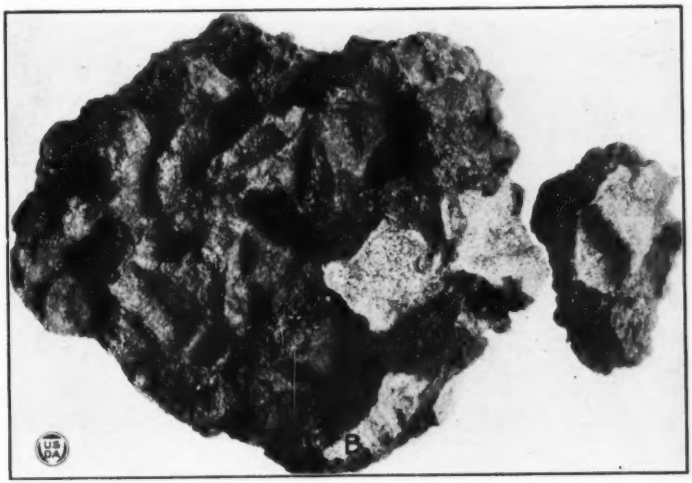
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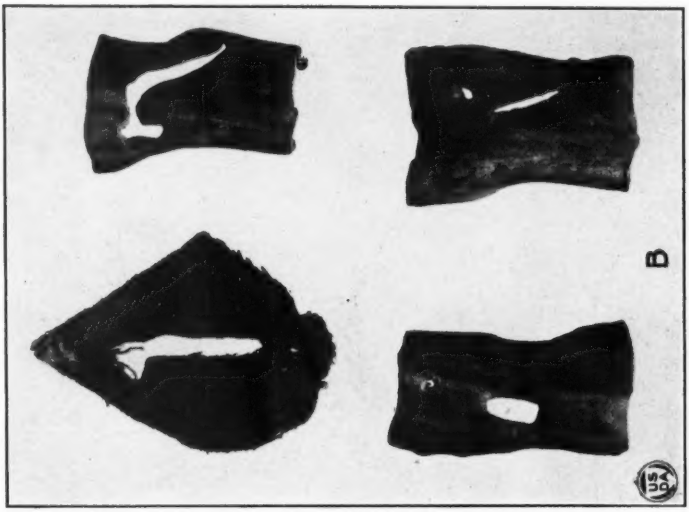
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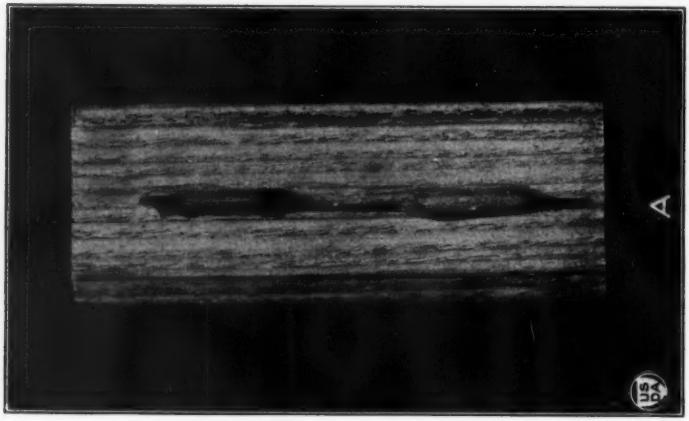

A

PLATE 6

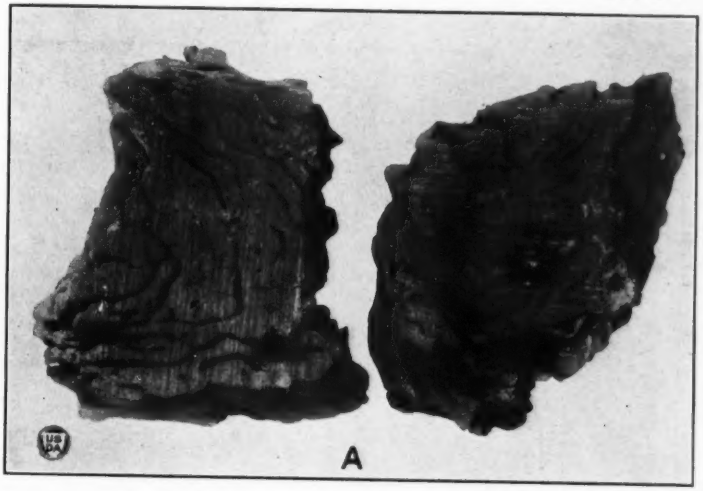
A.—Block of ash wood used by Dudley and Beaumont in studying Kalotermes in Panama; the best type of termitarium for studying Kalotermes.

B.—*Coptotermes niger*. Damage to lead sheathing of underground cable and perforations in tarred parcelling. Gold Hill, C. Z., Panama, October 29, 1916.

PLATE 7

A.—"Guayacan" (*lignum vitae*) entirely disintegrated by termites; all of the wood has been digested and excreted and then packed solid. From Balboa Shops, Canal Zone.

B.—Another section of the same species of wood showing structure built up of excreted wood by the termites. Note that it is a honeycombed instead of a compact mass as in A. *Lignum vitae* is one of the hardest woods known in the Tropics.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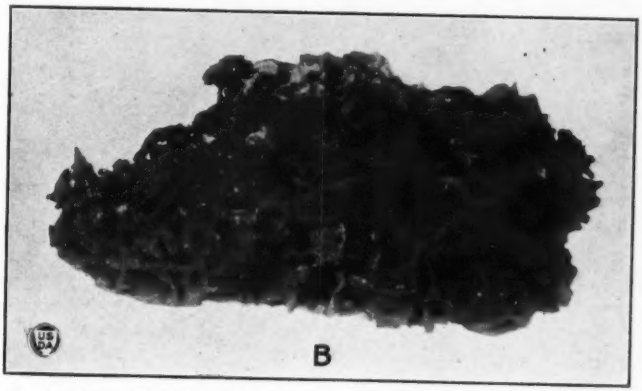
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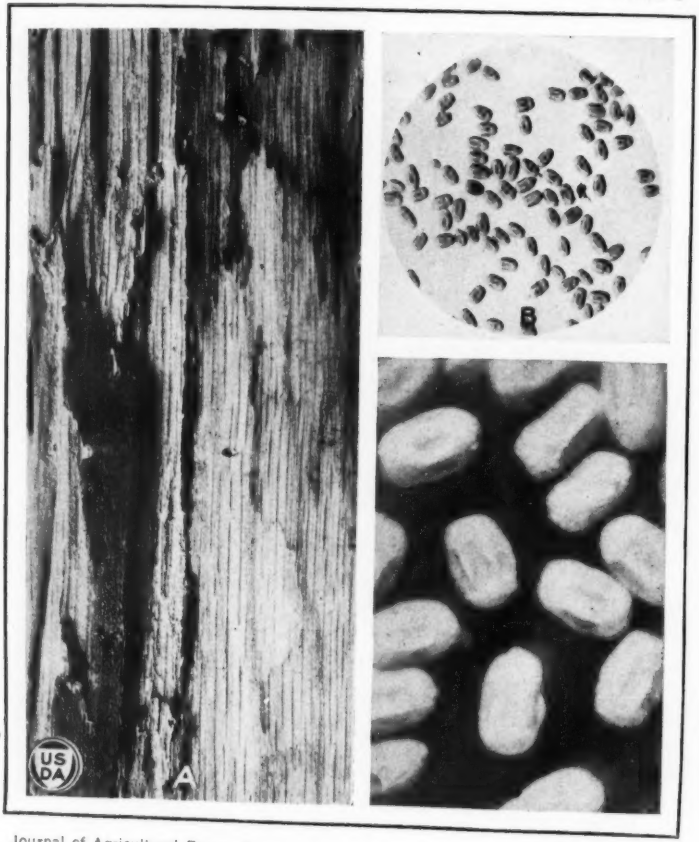
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PLATE 8

Cryptotermes thompsonae

A.—Section of oak base of revolving bookcase damaged by *Cryptotermes thompsonae*, Ancon, C. Z.
B.—Pellets of excrement from this wood. Natural size of pellet 0.54 by 0.85 mm.
C.—Same as B. More highly magnified to show impressions.

60378—24——3

THE ABSORPTION OF CARBON BY THE ROOTS OF PLANTS[1]

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In an experience of several years in fertilizer and nutrition investigations the writer frequently has had occasion to run cultures of wheat seedlings in solutions of the salts of the three fertilizer elements, nitrogen, potassium, and phosphorus, singly and in all combinations. When working under known conditions, with pure materials, on ashing the crop thus grown and dissolving the ash for a potassium or phosphorus determination, he has almost without exception found that the presence of nitrates in the solution is followed by the presence of carbonates in the ash.

Using the several kinds of salts singly and in all possible combinations and, as a control, a culture solution of distilled water only, the reaction of the ash toward hydrochloric acid has been observed to be as follows:

Culture solution.	Reaction.
Control, distilled water	No effervescence.
Sodium nitrate ($NaNO_3$)	Effervescence.
Potassium chlorid (KCl)	No effervescence.
Sodium phosphate (Na_2HPO_4)	No effervescence.
Sodium nitrate and potassium chlorid	Effervescence.
Sodium nitrate and sodium phosphate	Effervescence.
Potassium chlorid and sodium phosphate	No effervescence.
Sodium nitrate, potassium chlorid, and sodium phosphate	Effervescence.

It was also noticed, incidentally, that sodium carbonate in the culture solution would result in an ash that effervesced with acid, as would calcium and other carbonates, and also bicarbonates. A further interesting point noticed was that the absorption of an element of plant food is greatly influenced by the presence of a different element of plant food in the nutrient solution. For example, the absorption of potassium from a solution of potassium chlorid, of a definite concentration, may be doubled by the addition of sodium nitrate to the solution. These observations were followed by much work, carried on at intervals, which finally culminated in the two experiments here described.

About 1,000 seeds of Pacific Bluestem wheat were sprouted upon each of eight perforated disks floating in water. When the seeds had germinated and the plumules had reached a length of 1 cm., 200 of the best plants from each disk were transplanted to eight other disks, each of which was floated in 2,500 cc. of a different nutrient solution and placed under observation. In a day or two, in such cases, the plumule will grow through the perforations and the seedling establish itself in the solution. The solutions were not changed, but were kept up to volume with distilled water. When the plants had been under observation for 21 days, they were dried and weighed. One hundred

[1] Accepted for publication Aug. 11, 1923.

plants from each disk were ashed, the ash moistened with water and dissolved in hydrochloric acid, and the reaction was noted. The ashes were then analyzed for potassium. The experiment was repeated at another time. The results of the two series are shown in Tables I and II.

TABLE I.—*Results of tests and analyses of wheat plants grown with various nutrient solutions (first series)*

No.	Nutrient solution.	Reaction with HCl.	Potassium.	Per cent increase of K absorbed over No. 2.	Dry weight.
			Gm.		*Gm.*
1	Distilled water	No effervescence	0.0366	.....	4.10
2	500 ppm. KCl	No effervescence	.1435	.....	4.70
3	500 ppm. KCl, 500 $NaNO_3$	Effervescence	.2564	105	6.60
4	500 ppm. KCl, 500 Na_2CO_3	Effervescence	.1967	49	6.60
5	500 ppm. KCl, excess $CaCO_3$	Effervescence	.2095	61	5.40
6	500 ppm. KCl, 500 NaCl	No effervescence	.1432	0	5.00
7	500 ppm. KCl, 500 NH_4NO_3	Effervescence	.2547	103	5.80
8	500 ppm. KCl, 500 Na_2HPO_4	No effervescence	.1715	25	5.50

TABLE II.—*Results of tests and analyses of wheat plants grown with various nutrient solutions (second series)*

No.	Nutrient solution.	Reaction with HCl.	Potassium.	Per cent increase of K absorbed over No. 2.	Dry weight.
			Gm.		*Gm.*
1	Distilled water	No effervescence	0.0362	.....	4.20
2	500 ppm. KCl	No effervescence	.1766	.....	5.80
3	500 ppm. KCl, 500 $NaNO_3$	Effervescence	.2901	80	8.80
4	500 ppm. KCl, 500 Na_2CO_3	Effervescence	.2553	56	7.12
5	500 ppm. KCl, excess $CaCO_3$	Effervescence	.2321	39	6.40
6	500 ppm. KCl, 500 NaCl	No effervescence	.1931	12	7.28
7	500 ppm. KCl, 500 NH_4NO_3	Effervescence	.4114	166	10.40
8	500 ppm. KCl, 500 Na_2HPO_4	No effervescence	.2231	33	6.90

It will be noticed that, with the exception of the controls, the plants had an abundance of potassium always available. The problem became three-fold; first, to determine the influence of the different salts upon the presence of carbonates in the ash; second, to find whether or not the rate of absorption of a basic radical, potassium in potassium chlorid, for example, is affected by the rate of absorption of chlorin or some other acid radical, such as CO_3 or NO_3; third, to ascertain what use the plant is probably making of the absorbed radicals ordinarily considered of no value as plant foods.

By reference to Tables I and II it will be seen that in every case carbonates were found in the ash of the plants where sodium nitrate, sodium carbonate, calcium carbonate or ammonium nitrate occurred in the culture solution. No carbonates were found in the ash of the controls or in the cultures where potassium chlorid alone or in combinations with sodium chlorid or sodium phosphate was used in the culture solutions.

When sodium carbonate goes into solution the salt is partially ionized with the formation of sodium ions which bear a positive charge and CO_3 ions which bear a negative charge. A CO_3 ion will also be formed when calcium, magnesium, potassium or any other carbonate goes into solution. The plant seems to feed upon ions only. The results of these experiments suggest that the plant, when grown in a solution containing a dissolved carbonate, absorbs the CO_3 ion by means of its roots.

Under normal conditions most plants feed more heavily upon nitrates, or nitrate radicals (NO_3), than they do upon such basic radicals as sodium or calcium. When sodium nitrate occurs in a solution the normal rate of absorption of NO_3 by plants of this age, in comparison with that of sodium, is about in the ratio of 10 to 1. The plant first takes up the NO_3 ion, leaving the solution basic with sodium; the sodium then by combining with water becomes a hydroxid and this in turn combines with the carbon dioxid dissolved in the nutrient solution from the air or from that given off by the roots, and forms sodium carbonate (Na_2CO_3) or bicarbonate ($NaHCO_3$). The plant then seems to absorb the ionized CO_3 or HCO_3 radical of the carbonate thus formed. As fast as the CO_3 or HCO_3 radical is taken up by the plant, the sodium again through the agency of water unites with the carbon dioxid of the solution, and more sodium carbonate or bicarbonate is formed.

There is some reason for believing that a demand for any element of plant food must exist within the plant before much of it can be absorbed. A certain amount of almost any salt available in solution will be taken up by the plant, but the amount will be small if the salt be useless. The demand generated in the tissues is the one which dominates absorption, and a plant can not be forced to take up any considerable amount of material not needed.

There are strong indications that the plant absorbs the CO_3 ion from solution by means of its roots, and that the carbonate may be derived from mineral carbonates, the bases of which may take up carbon dioxid from the air or from the carbon dioxid dissolved in the solution. The absorption of CO_3 does not seem to take place unless some soluble base is present. Upon more than one occasion sets of wheat seedlings have been grown for two weeks or more in such solutions as, (a) distilled water (control), (b) distilled water, saturated with carbon dioxid gas every day, (c) distilled water, with excess of ferric hydroxid, saturated with carbon dioxid every day, (d) distilled water, with excess of aluminum hydroxid, saturated with carbon dioxid every day, (e) distilled water, with excess of calcium carbonate, saturated with carbon dioxid every day. With ferric hydroxid and aluminum hydroxid the plant had to deal with relatively insoluble bases, while in the case of calcium carbonate it had a slightly soluble salt. Only when calcium carbonate was present did an ash result that effervesced with acids. Distilled water saturated with carbon dioxid would in a few hours come practically into equilibrium with the air. Nevertheless, for a considerable time, especially in cold weather, a large amount of gas would be held in the water as carbonic acid, (H_2CO_3), and this would be ionized slightly, with the same ions, HCO_3, and probably a very small amount of CO_3, as were in solution in the case of sodium bicarbonate. With sodium bicarbonate the ions appear to be readily absorbed, but in the case of carbonic acid it seems impossible for the plant to absorb them. This phenomenon of nutrition as shown by the plant may either be indicative

of some difference in ionization now not recognized, or, more probably, may be due to the exceedingly small amount of CO_3 and HCO_3 ionized.

Carbon is one of the most important elements entering into a plant's composition. We have been taught that the source of supply of carbon is the carbon dioxid of the air, and that the absorption of this gas takes place through the leaves of the plant. Evidently, judging from the experiments just described, there is another source of carbon, and another way of absorbing it into the plant system.

We are also accustomed to think that the only use of carbon in the plant's economy is in building up organic compounds, such as cellulose. Considered as the atom carbon, this may be true, but it seems reasonable to assume that a plant would not demand the radical CO_3 unless it had some special use for it. To determine if carbon derived from this source can be used by the plant in building up cellulose and similar compounds, the following experiments were conducted:

Culture pans, each containing 175 wheat seedlings, were grown out-of-doors, in cool weather, for 60 days, using distilled water, with and without salts in solution, and under other conditions described in Tables III and IV, and the dry weights of 100 plants from each pan determined.

TABLE III.—*Dry weights of wheat plants grown under specified conditions (first series)*

No.	Conditions.	Dry weight, 100 plants.
		Gm.
1	Distilled water, pan uncovered	5.850
2	Distilled water, covered with a bell jar and sealed with adhesive tape against outside air	2.617
3	Distilled water, with excess of $CaCO_3$, uncovered	6.634
4	Distilled water, with excess of $CaCO_3$, covered with bell jar with a water seal	3.667
5	Distilled water, with 137 ppm. $NaNO_3$, uncovered	6.456
6	Ditilled water, with 137 ppm. $NaNO_3$, covered with bell jar and sealed with tape	2.764
7	Distilled water, with 137 ppm. $NaNO_3$ and excess $CaCO_3$, covered with bell jar and water sealed	2.900

TABLE IV.—*Dry weights of wheat plants grown under specified conditions (second series)*

No.	Conditions.	Dry weight, 100 plants.
		Gm.
1	Distilled water, uncovered	4.76
2	Distilled water, covered with bell jar and hermetically sealed with paraffin	3.23
3	Distilled water, with 137 ppm. $NaNO_3$ and excess of $CaCO_3$, uncovered	6.11
4	Distilled water, with 137 ppm. $NaNO_3$ and excess of $CaCO_3$, covered with bell jar and hermetically sealed	3.85

Since the amount of carbon dioxid originally contained in the air of the bell jar in each case was insignificant, no attempt was made to wash it out before beginning the experiment. The plants were grown in the

direct sunlight, which made it necessary to spray one side of the bell jar with whitewash to prevent the plants from being blistered. The plants grown under the bell jar had as good a color as those grown outside, and were quite thrifty, but showed a greater tendency to spindle up on account of the modified light. The dry weights were taken as an indication of the amount of cellulose and other organic compounds which had been formed under the various conditions. Since this seemed fairly accurate, no direct determination of the carbon was made.

It will be seen by reference to the tables that the plants grown in the open increased about 100 per cent in dry weight over those having the same treatment but grown under bell jars. The plants in numbers 4 and 7, Table III, had an abundance of carbon in solution as a carbonate, but did not seem able to utilize it in tissue building. The variation in dry weight was rather wide, as might have been expected, but by comparing the plants in each culture pan grown under a bell jar with those in a pan having the same treatment but grown in the open, it seems quite evident that the plant is unable to substitute, to any appreciable extent, the carbon of the CO_3 radical absorbed by the roots for the carbon of the carbon dioxid taken in by the leaves.

In the experiments here recorded there are suggestions that the carbon needed for building up organic compounds in the plant is derived from the carbon dioxid of the air, and not from the CO_3 taken into the plant through the roots. Nevertheless, it is evident that plants demand CO_3, and will absorb it under certain conditions, to the benefit of the plant. The writer finds it advantageous to have a little calcium carbonate present in nutrient solutions, or, if this is not feasible, a little sodium carbonate.

The stimulative influence of sodium carbonate is noticeable in soils that have a small amount of black alkali. In many instances the beneficial effect of sodium nitrate seems to be partly due not only to the nitrate radical (NO_3), as is generally supposed, but also to the excess of the base which the absorption of NO_3 leaves in the solution to act as a go-between in indirect absorption of carbon dioxid by the plant. The experiment has been performed of taking two portions of the same nutrient solution, each containing 100 ppm. of sodium nitrate, keeping in one a large number of healthy wheat seedlings for a few days until the nitrate radical, NO_3, is entirely absorbed, then removing the seedlings, placing small seedlings in both portions and allowing them to grow. When this growth begins, one portion of the nutrient solution still contains 100 ppm. of sodium nitrate, or about 72 ppm. NO_3 available as plant food, while the other has no nitrates. For two or three weeks the plants are often found to grow equally well in the two solutions. Both solutions contain approximately the same amount of sodium, as a nitrate in one case and a bicarbonate in the other. A wheat plant of course can not continue to grow indefinitely without an adequate supply of nitrogen; but during the seedling stage, while there is still some plant food stored up in the seed, the plants will often grow equally well in the two nutrient solutions.

The writer has observed that the ash of the so-called "lime-loving" plants usually runs very high in carbonates, while the ash of plants that have been grown upon acid upland soils often runs extremely low in this respect. This may be true of acid-loving plants like the blueberry and cranberry, which grow best in acid lowland soil, but adequate

data upon these plants are lacking. Almost without exception the alkalinity or basic character of a soil is due to carbonate of lime, which is the form of lime that a great class of plants "love." Eliminating the so-called "antagonistic" effect of calcium, it is significant that these plants "love" other forms of lime, such as calcium chlorid or calcium nitrate, little more than they "love" the same compounds of potassium or sodium. The limit of endurance of plants for the common calcium salts, the sulphate, chlorid, nitrate and carbonate, is usually higher than for the corresponding sodium salts, because the plant, in its adaptation, is more accustomed to the salts of calcium than to those of sodium. As far as the beneficial effect is concerned, there is little difference between calcium chlorid and sodium chlorid, or between calcium nitrate and sodium nitrate. When a compound of lime, such as calcium hydroxid, which the plant has never encountered in its age of adaptation, is placed in a culture medium, it is even more toxic than the same compound of sodium. For instance, calcium hydroxid is much more toxic to the plants that the writer has worked with than are sodium hydroxid or potassium hydroxid.

It is calcium carbonate that determines whether or not a plant is "lime-loving," and one can often produce the same type of beneficial results with potassium carbonate. It is not unreasonable to question the application of the term "lime-loving" as applied to plants. The term might more properly be "carbonate-loving."

Assuming that there is a demand for CO_3 within the tissues of a plant, that in response to the demand this radical is absorbed by the roots, and that the carbon thus obtained is not used to any great extent in building up carbohydrates or other carbon compounds, a different hypothesis is needed to explain the fondness of the plant for carbonates.

Some work has been done upon the relation of the reaction of the plant sap to the action of the culture solution. Hoagland [2] has shown that the plant tends to adjust the action of a nutrient solution in the direction of the reaction of its own sap by absorbing the acid or basic radicals in the proportion needed to accomplish its purpose. Since the completion of the work here reported, Truog [3] has produced evidence tending to show that carbonates or bicarbonates may be used in the regulation of the action of plant proteins and the plant sap in precipitating oxalic and other acids out of solution in the sap. The writer's experiments indicate that the plant probably absorbs the CO_3 ion or exudes CO_2 in order to maintain equilibrium in its tissues.

Referring again to Tables I and II, it will be seen that the absorption of a base, like potassium, seems dependent to a large extent upon the absorption of an equivalent amount of an acid radical or upon the neutralizing action of some other salt in the nutrient solution. The selective absorption that is so highly developed in plants is marked in the absorption of potassium. A rapid absorption of potassium from a nutrient solution would not only leave the solution acid, but would tend to make the plant sap basic. If the plants feed upon ions bearing electric charges, and if these charges are not discharged when the ions enter the system, it is not supposable that either the nutrient solution or the plant sap will remain long out of equilibrium with respect to positive or nega-

[2] HOAGLAND, D. R. THE RELATION OF THE PLANT TO THE REACTION OF THE NUTRIENT SOLUTION. *In* Science, n. s., v. 48, p. 422–425. 1918. Bibliographical footnotes.

[3] TRUOG, E. THE FEEDING POWER OF PLANTS. *In* Science, n. s., v. 56, p. 294–298. 1922. Bibliographical footnotes.

tive charges. If, during the rapid absorption of potassium, there should be a tendency for the sap to become too basic, an absorption of CO_2 would follow. On the other hand, a rapid absorption of an acid radical, such as NO_3, would necessitate an exudation of CO_2 if equilibrium is to be maintained. This phenomenon of absorption and exudation of CO_2 for such a purpose holds in animal physiology, and the proof is not wanting that there is a striking analogy within the plant.

The second column of Table I presents data upon this phase of absorption. With an abundance of potassium present as potassium chlorid, as in number 2, the absorption of potassium, including that originally contained in the seed, reached 0.1435 gm. for a total of 100 plants. With sodium nitrate present, however, the absorption reached 0.2564 gm. Subtracting the amount originally in the seed from both of these figures, we find an increase in the absorption of 105 per cent resulting from the presence of sodium nitrate. Ammonium nitrate, in number 7, produced an absorption almost as great, followed in the order named by calcium carbonate, sodium carbonate, and sodium phosphate. Sodium phosphate is an alkaline salt, and, while it may prevent the nutrient solution from becoming acid during a rapid absorption of potassium, it carries no carbonate radical and produces no effervescence in the ash. At this stage of growth the normal rate of absorption of potassium by wheat seedlings is about equal to the absorption of NO_3, and therefore with both potassium chlorid and sodium nitrate present in the culture solution conditions are ideal for the maximum absorption of potassium. When potassium chlorid alone is present in the nutrient solution the absorption of potassium is limited. With the addition of a salt not possessing the power of becoming alkaline under the conditions of the experiment, such as the sodium chlorid in number 6, no increase in the absorption of potassium was noted in the experiment. This regular order of the absorption of potassium will probably not be maintained in all experiments, but, with extreme care to eliminate all disturbing factors, it seems likely that the general order of these results will be maintained as is shown in Table II.

When sodium nitrate is present in culture solutions, the opposite condition prevails at the beginning of absorption from that which prevails with only potassium chlorid present. There is a demand and consequently a rapid absorption of the nitrate ions, NO_3, which leaves the solution alkaline with an excess of base and the plant sap with an excess of negative charges. Under these conditions the plant seems to be able to exude CO_2, which tends to bring the sap into equilibrium, and enters into combination with the basic radical sodium, in the culture solution, to form sodium carbonate or bicarbonate. There may thus be an exchange of acid radicals between plants and the nutrient solution. The solution may also absorb carbon dioxid from the air, and this may enter into the same compounds with the sodium.

The alkalinity of a sap may be overcome in two ways, first by an exudation of some base not needed in the plant, or by the absorption of some acid. The plant in its adaptation has elected to absorb an acid, CO_2, rather than to exude a base. Similarly, the acidity of the sap may be overcome by the absorption of a base or by the exudation of an acid radical, and the plant in its adaptation seems to have developed the power to do both. Carbon dioxid, under natural conditions of growth, is practically always present in solution and available, and the CO_2

content of the soil air is usually much higher than that of the overlying atmosphere. If the plant, in its ages of adaptation, has felt the stimulus of absorbing or exuding an acid it is reasonable to suppose that it may have selected CO_2 in preference to all others.

Carbon dioxid seems to be present in combination with some soluble base in practically all soil solutions. The writer has never analyzed a soil solution that did not contain at least some bicarbonates. If, for example, only a few parts per million of calcium or sodium are present in the soil or culture solution, the carbonate radical necessary for combination with such a small amount of base would not necessarily be sufficient to cause a perceptible effervescence with acid; but it must be remembered that the CO_3 ion may be absorbed by the plant, while the calcium or sodium ion may remain in the solution to unite with the CO_2 contained, and form more $CaCO_3$ or Na_2CO_3, which in turn gives up its CO_3 to the plant. The amount of the carbonate ion which may be absorbed is therefore out of proportion to that originally combined with the calcium. In localities where waters high in calcium carbonate abound, or where the soil is calcareous, it is very difficult to keep control cultures, or cultures where no carbonate is supposed to be, entirely free from carbonate. The dust from the air in settling over a culture solution often may contain enough lime to cause the ash of the plants to effervesce with acid. In accurate work the plants must be shielded from all such sources of lime, and the culture pans and aluminum disks must be rinsed off with dilute acid before beginning the experiment.

If practically all the phenomena of plant physiology are but phenomena of adaptation, as the writer firmly believes, the theory that the plant uses the carbonate radical in order to maintain equilibrium in its tissues is perfectly reasonable. In the culture solution containing only potassium chlorid the absorption of potassium was checked because of the acidity of the solution. Under field conditions this acidity is cared for naturally, as the great majority of our upland soils are basic, either with lime or magnesium carbonates, or with the oxides of iron or aluminum. The plant, therefore, in its adaptation, has never felt the stimulus of exuding a base in order to prevent the soil solution from becoming acid. The writer has never been able, by the use of many methods, to force a plant to exude a base in appreciable amounts. On the other hand, the plant has felt the stimulus of exuding an acid radical, as the hydroxids of the alkalies are much more toxic than the carbonates or bicarbonates.

With plants that thrive in bog soils it is possible to conceive of a scarcity or even an absence of aerobic bacteria, and the consequent scarcity of carbon dioxid. This might cause such plants to develop a different system. Soluble silica or some other acid radical might be used instead of CO_3 to maintain equilibrium in the tissues. The high silica content of many such plants may perhaps be ascribed to this process.

The absorption of any element of plant food is probably dependent upon the state of equilibrium of both the plant sap and the nutrient solution. This equilibrium may not necessarily be neutral, but may be either acid or akaline, and it will probably be different with each plant. Further, the plant in absorbing food may have certain powers of accommodation enabling it to absorb upon both sides of the equilibrium line at almost the same time. This absorbing zone will probably be wide with some plants and narrow with others.

CONCLUSIONS

(1) The presence of sodium or ammonium nitrate, or of calcium, sodium, or potassium carbonate, in culture solutions for wheat seedlings is followed by the presence of carbonates in the ash of the plants.

(2) When sodium nitrate, for example, is present in the culture solution the plants seem first to absorb the NO_3 ion, leaving in the solution some sodium which combines with the water and with the CO_2 dissolved in the solution to form sodium carbonate or bicarbonate. This in turn gives up its CO_3 to the plant.

(3) The plant absorbs CO_3 by means of its roots.

(4) The plant probably absorbs CO_3 as an ion, or exudes CO_2, for the purpose of maintaining equilibrium in its tissues or in the nutrient solution.

(5) Wheat plants do not seem to be able to absorb CO_2 from its solution in water without the presence of a soluble base.

(6) The absorption of a basic radical, potassium for example, seems to depend largely upon the absorption of an acid radical.

(7) There is a possibility that the term "lime-loving" as applied to to plants, might more properly be "carbonate-loving."

OAK SAPLING BORER, GOES TESSELATUS HALDEMAN[1]

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NATURE OF INJURY

During the last 10 years the writer has observed in several localities of central West Virginia rather extensive injury to young oak and chestnut trees by cerambycid larvæ of the species *Goes tesselatus* Haldeman. The injury done consists of wide irregular burrows in the wood at the base of the trunks. Trees from half an inch to 2 inches in diameter suffer most. (Pl. 1, D, E, F; Pl. 2, A.) Approximately 25 per cent of the infested trees die, either directly from the injury inflicted by the larvæ or from breaking a few inches above the ground (Pl. 3, A, B) at the large exit holes made by the escaping beetles. In the woods the insects show a distinct tendency to colonize, some apparently favorable growths of saplings being almost free from injury and others with practically every young tree showing fresh or ancient wounds.

The burrows are most extensive a few inches above the surface of the ground but they extend also a short distance below. The larvæ hatch and begin feeding about midsummer, and during the remainder of the first season they burrow in the outer wood, both above and below the oviposition scar in the bark. As cold weather approaches they work downward and pass the winter near the ground level. The second season they bore deeper into the wood and their galleries thereafter are in and around the heart. The burrows are so large that often a considerable portion of the trunk at the place of attack is involved (Pl. 1, D). When 4 or 5 inches above the ground, the burrow is enlarged at the upper end to form a pupal chamber.

LIFE HISTORY

BEETLE AND EGG

The beetle (Pl. 2, C, D) is elongate, cylindrical, with a ground color of grayish brown. The body is covered throughout with short, yellowish, prostrate hairs, these hairs on the elytra varying locally in abundance, and by their density in places forming small, scattering, yellowish spots. The antenna is much longer than the body in the male and slightly longer than the body in the female. The female is somewhat larger and stouter than the male. Numerous reared specimens ranged from 20 to 27 mm. in length and from 7 to 9 mm. in width.

After attaining the adult stage the beetle remains in the pupal chamber from 5 to 7 days and then escapes through a circular hole gnawed through the bark at the upper end of the chamber (Pl. 2, C). This hole is from 7 to 9 mm. in diameter, and the smaller trees sometimes break at the hole as a result of the severing of so much of the wood (Pl. 3, B).

[1] Accepted for publication Aug. 11, 1923.

[2] The investigations described in this paper were authorized by Dr. A. D. Hopkins, Forest Entomologist.

The beetles are somewhat sluggish and evidently do not move about a great deal under natural conditions. In color they resemble the bark of the trees upon which they rest, and they are hard to find in the woods. The writer has never been able to obtain an adult specimen except by rearing. When confined in cages the beetles gnaw the bark freely from white oak twigs, and when supplied with sufficient of this kind of food they live from three to five weeks.

The beetles issue from the wood late in May and early in June. At French Creek, W. Va., where beetles have been reared for several successive seasons, the first emergence record is May 25 and the last June 1. Within a week or ten days after emergence the beetles begin ovipositing. In preparing a place for her egg the female gnaws a circular concavity from 6 to 12 mm. in diameter in the bark (Pl. 1, A). In the center of this rather conspicuous scar she inserts her ovipositor and deposits a single egg between the bark and wood. Of about twenty eggs observed in their natural positions, all were placed with the long axis parallel to the grain of the wood and were directly above the oviposition scar in the bark (Pl. 1 B, C). The distance from the entrance hole to the near end of the egg was uniformly about 1 mm. The space between the egg and the hole is filled with a brownish, gluelike substance which becomes hard when dry.

The egg (Pl. 1, B, C) of the oak sapling borer is elongate, yellowish white, parchmentlike, and wrinkled. The dimensions average 6 mm. long by 2 mm. wide. When the egg is removed from its position in the tree the impress of the wood grains usually shows distinctly on its surface.

Beetles confined in the insectary oviposited freely in sections cut from the trunks of young white oak saplings and also in white oak bushes in the woods when confined over them. In one young white oak over which females were caged, 12 egg punctures were made. Of these punctures, 11 were within 4 inches of the ground and 1 was 15 inches above the ground. One lot of 5 females laid a total of 30 eggs, or 6 per individual. No definite data were obtained as to the time required by the egg for hatching, but general observations indicated an incubation period of about three weeks.

LARVA

Immediately after hatching the larva begins to feed in the bark and soon after that to eject sawdustlike castings through the oviposition wound and other small openings which it eats to the surface. During the second season of feeding these castings are thrown out near the ground and often form small, conspicuous heaps at the base of the tree. The larval period covers three years, and, in some cases, probably four or five years.

Individuals of various sizes may be found in the trees at any season of the year. The smaller specimens are usually located just beneath the bark, while the larger ones are deeper in the wood. At all stages of their growth the larvæ are slow of movement, but they show great strength in burrowing through the hard wood and in tearing off loose strings of wood for bedding their pupal quarters.

During its last summer in the tree the larva excavates a gallery extending several inches up the trunk and forms a roomy pupal chamber at the upper end (Pl. 1, D). This is entirely within the hard wood of the tree. The gallery below the chamber is packed with excelsiorlike wood fiber (Pl. 1, D; 2, A) through which moisture may drain. At the upper

end of the chamber an extension of the gallery turns abruptly outward, reaching almost to the inner bark. In this chamber the full-grown larva passes the winter and pupates early in the spring.

DESCRIPTION [1]

The full-grown larva is from 25 to 30 mm. long, the width of the prothorax is between 5 and 6 mm., and the head is about 4 mm. wide.

The Goes larva belongs to the general type of longicorn larvæ, which are specialized for a typical wood-boring life. The body, robust, fleshy, and yellowish, is almost cylindrical but slightly flattened dorsally and ventrally and somewhat broader anteriorly. The abdomen is extended and the segments readily telescope. The head is invaginated into the prothorax, with the exception of its minor anterior part, which carries the movable labrum and large membranous clypeus, the forceful mouth parts, and the different sensory organs. As in all members of the subfamily Lamiinae, to which Goes belongs, the shape of the head is very characteristic; it appears oblong when liberated and has almost parallel sides and a long unpaired suture along the dorsal middle line. It penetrates the entire length of the prothorax and its posterior foramen is located more ventrally than in the longicorn larvæ of the other groups, thus making the movements of the head and especially the up-and-down movements more free than in these larvæ.

In Goes the sides of the head narrow gradually to the base, while in closely related genera they suddenly constrict behind the middle of the head; the anterior chitinized and dark margin of the head capsule is without particular limitation posteriorly, not especially thick, and not projecting; the eyes are small, only one ocellus is present on each side; the antennæ are very small, and the chitinous rings of the head capsule from which they extend are closed behind, not bisected by the frontal sutures, as is the case in related genera. The mandibles are strong and heavily chitinized, as in all longicorn larvæ, but they have a rather unusual shape, being elongate, with a short, oblique cutting edge, and therefore they produce very characteristic scars or marks in the surfaces of the galleries which they gnaw. As in all the genera of the subfamily to which it belongs, Goes is completely legless, and its locomotion is therefore entirely dependent on the large warts or "ampullæ" of the abdomen. These warts are present in all longicorn larvæ, usually developed on the dorsal and ventral sides of the posterior thoracic and the first seven abdominal segments, and their surfaces are subdivided in different ways by small furrows or wrinkles and often set with minute chitinous asperities.

It has been noticed that a striking correlation exists between the development of the surfaces of the ampullæ and the different environments in which the longicorn larvæ live. Thus the chitinous asperities are characteristic of the forms in living trees and glabrous ampullæ in the forms in dead wood. Therefore the presence or absence of these asperities offers good classifying characters, especially for the distinction of species. Applied to the genus Goes, it is found that in five of its six known species the dorsal warts of the abdominal segments carry four transverse rows of small tubercles set with rather coarse asperities, and all of these species, among which is *Goes tesselatus*, attack living trees; the sixth species has glabrous ampullæ and has only been found in dead wood, feeding beneath the bark.

In many longicorn larvæ the dorsal surface of the ninth segment is provided with one or two chitinous plates or terminates with an unpaired median thorn or carries small hooks or chitinous granules; in Goes it is covered with a single smooth shield, shaped like a nail, posteriorly rounded and of a light yellowish color.

The spiracles are lateral, oval, with two lips and a narrow linear opening. Nine pairs are present; the mesothoracic is twice as large as the abdominal ones and is pushed somewhat forward into the prothorax.

Very remarkable but easily overlooked structures are two minute chitinous pits or pores, one at each end of an oval, obliquely transverse tubercle, on the sides of the first eight abdominal segments. These pits represent the external ends of a sensorial organ which is concealed in the pleural tubercles and probably is some sort of ear or so-called "chordo-tonal" apparatus. The shape of these pleural tubercles, the number of the setæ which they carry, and the more or less distinct development of the pits offer good generic characters in the subfamily to which Goes belongs. In Goes each tubercle is broadly oval; it carries two setæ, and the pits are darkly chitinized and comparatively distinct.

[1] By Adam G. Böving, Forest Insect Investigations, Bureau of Entomology, United States Department of Agriculture.

The structure of the integument of the body and the development of the hairs vary, like the asperities of the locomotory warts, according to the environment. In *Goes tessellatus* the texture of the integument is tough, shining, and sparsely clothed with hairs; but these hairs are long, rather coarse, and distinctly colored brownish yellow. Anteriorly the dorsal side of the prothorax is smooth, and the hairs on its front margin do not form a continuous band as they do in closely related forms; posteriorly it is finely asperate. On the ventral side the posterior area of the prothoracic sternum carries a band of asperities which in this species is broken for a short distance in the middle.

PUPA

In West Virginia pupation has been observed to take place from April 9 to April 15. The pupa is yellowish white and is capable of only feeble movement. With four individuals the pupal stage lasted 39, 41, 43, and 44 days, respectively.

DESCRIPTION [4]

The pupa measures about 25 mm. in length. As in all the longicorns, it bears considerable resemblance to the adult, and many characters are identically developed in the two stages. However, special pupal characters are found in the striking way in which the posterior half of the long antennæ is rolled into a spiral below the abdomen and also in the shape, number, and arrangement of hairs or spines on many parts of the body. The hairs are yellowish brown and more coarse and well colored than in other species of Goes; they are rather numerous on the prothorax and are along the back of the first six abdominal segments set in two conspicuous longitudinal series of large blotches; each of the two blotches on the first abdominal segment contains about twice as many hairs as on the sixth segment. Finally, the last abdominal segment is armed with a well-developed, single, median process, which is conical, recurved, and mostly fleshy, but at the tip hardened into an acute and dark spine which laterally carries several minute teeth.

DISTRIBUTION

According to Blatchley,[5] this species is known from New York, Indiana, Louisiana, and Georgia. Its presence in West Virginia, which is central in the quadrangle of States mentioned, indicates that it may occur, locally at least, throughout much of the eastern portion of the United States where oak and chestnut trees grow. Notes in the files of the Bureau of Entomology show that the species has been observed in Virginia and North Carolina.

FOOD PLANTS

By far the most extensive injury caused by the oak sapling borer is to white oak, *Quercus alba*, although the adult insects have been reared from chestnut oak, *Q. prinus*, and injury probably attributable to this species has been noticed in other oaks. More rarely it attacks young chestnut trees, *Castania dentata*. In 1915 the writer obtained one beetle of this species among individuals of the roundheaded apple-tree borer, *Saperda candida* Fab., reared from wood of young service trees, *Amelanchier canadensis*, collected in the woods. It seems that the insect is a general feeder, but with a decided preference for white oak.

[4] By Adam G. Böving, Forest Insect Investigations, Bureau of Entomology.

[5] BLATCHLEY, W. S. AN ILLUSTRATED DESCRIPTIVE CATALOGUE OF THE COLEOPTERA OR BEETLES (EXCLUSIVE OF THE RHYNCHOPHORA) KNOWN TO OCCUR IN INDIANA. Bul. 1, Ind. Dept. Geol. and Nat. Resources, p. 1068. 1910.

NATURAL ENEMIES

No insects predacious or parasitic upon the oak sapling borer have been discovered. Woodpeckers destroy many of the larvæ and pupæ by drilling through the wood and removing them from their burrows (Pl. 3, C). The species of bird responsible for the destruction of the borers was not determined, but the marks made in removing the insects were noticed frequently in woods where both the hairy woodpecker, *Dryobates villosus villosus* (L.), and the downy woodpecker, *Dryobates pubescens medianus* (Swains.), were abundant.

CONTROL

Control measures against this insect will occasionally be called for where chestnut trees planted for nut production and oak and chestnut trees planted for shade, park, and reforestation purposes are attacked. Fortunately the borer in the tree makes its presence known by ejecting castings from its burrow before great injury has been done. Wherever fresh castings are being thrown out the borers can be located and killed without much difficulty by the use of a knife or chisel and a short piece of wire. A little cutting of the bark and outer wood is usually sufficient to expose the burrow so that the wire can be inserted and the borer killed.

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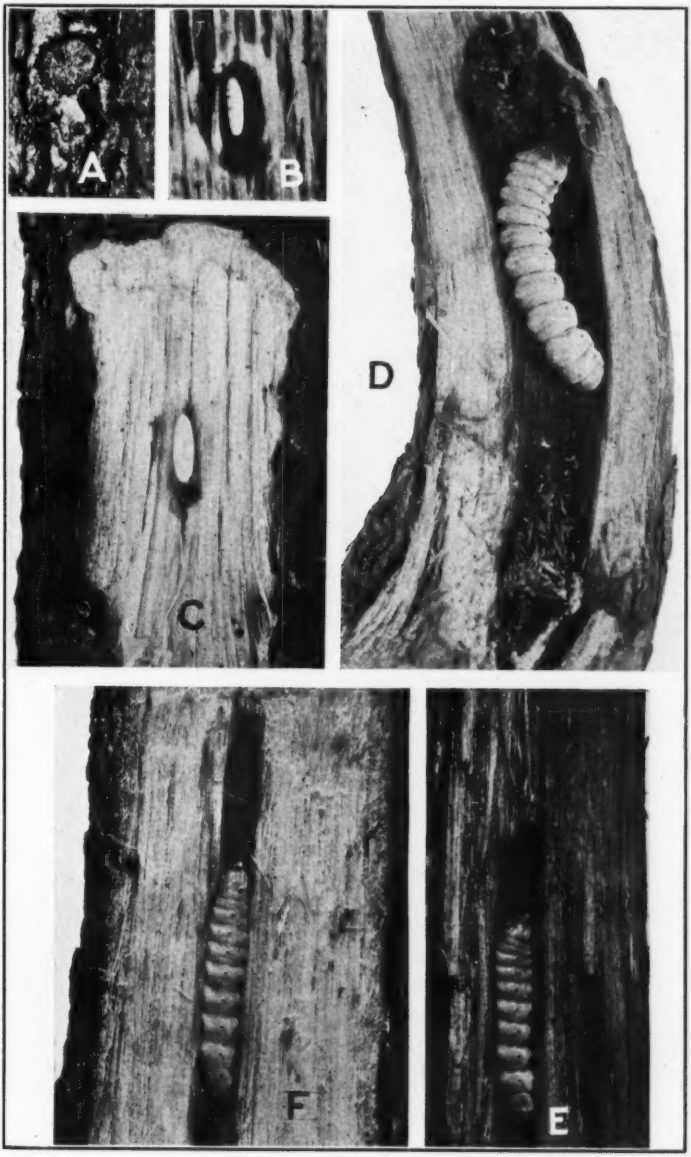
PLATE 1

Goes tesselatus:

A.—Oviposition scar in bark of oak. About natural size.
B and C.—Eggs exposed by removing bark. Slightly enlarged.
D, E, and F.—Larvæ in their burrows. About natural size.


A
B
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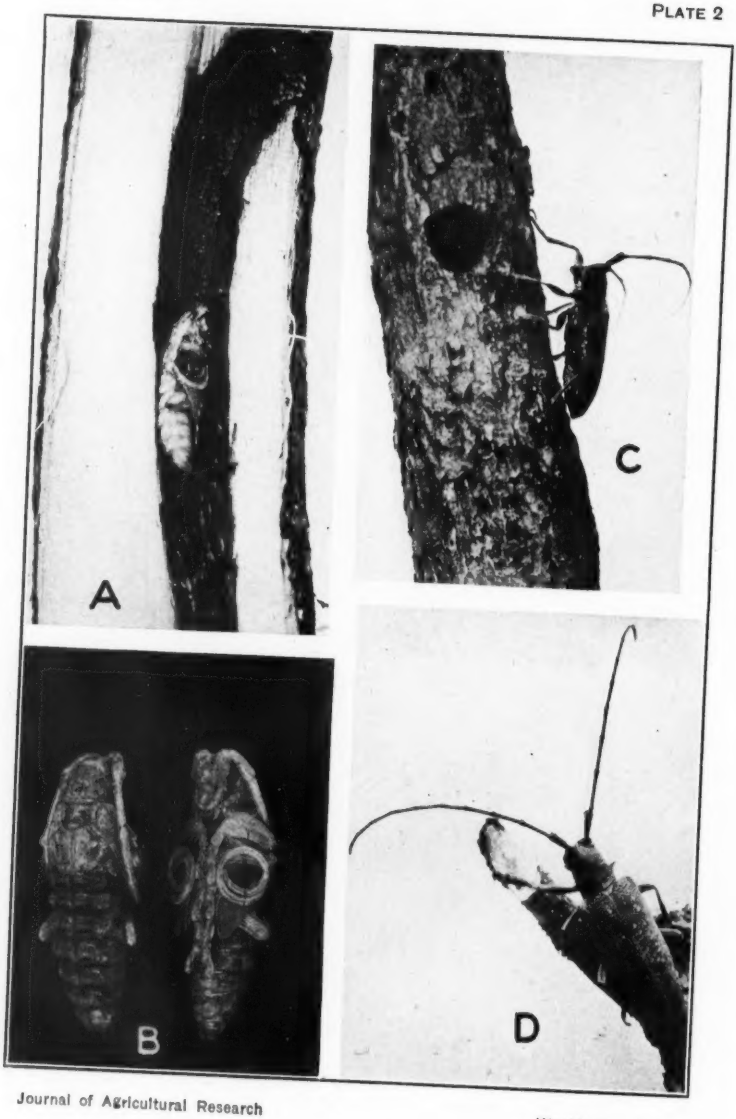
E



A.—
B.—
C.—
D.—

PLATE 2

Goes tesselatus:

A.—Pupa in natural position in tree. About natural size.
B.—Pupæ. Enlarged.
C.—Beetle just after emerging from wood. About natural size.
D.—Beetle. Slightly enlarged.

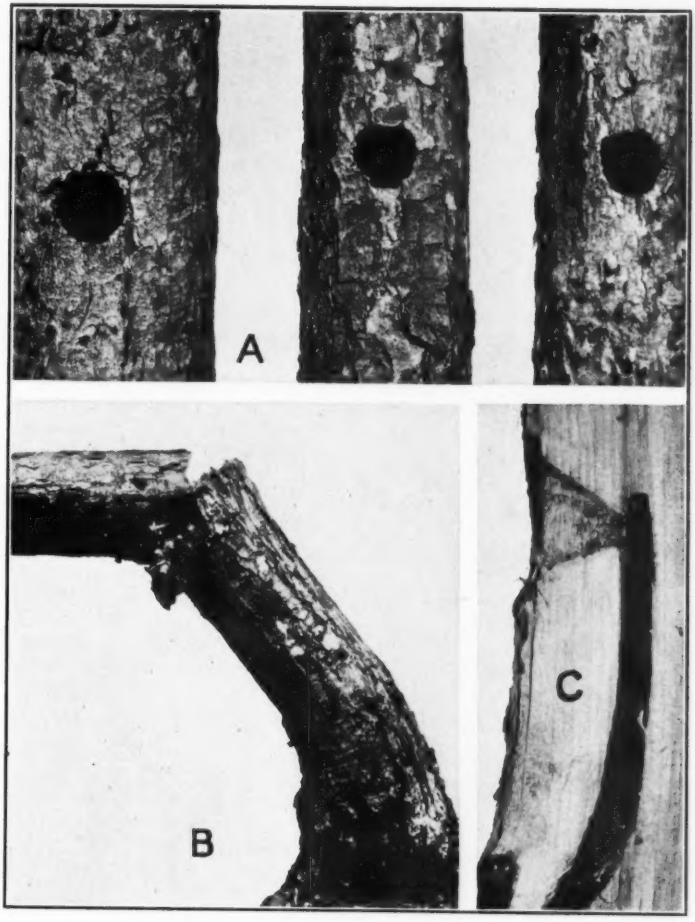
PLATE 3

Goes tesselatus:

A.—Trunks of saplings showing large exit holes of the sapling borer.

B.—Young oak tree broken by wind at exit hole of sapling borer. About natural size.

C.—Drill mark of woodpecker made in removing a borer from its burrow. About natural size.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BUD SELECTION AS RELATED TO QUANTITY PRODUCTION IN THE WASHINGTON NAVEL ORANGE.[1]

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INTRODUCTION

Studies of bud variations in citrus varieties were begun by the senior writer at Riverside, Calif., in April, 1909. These investigations have been carried on largely in plats located in successful orchards of the important California varieties, and detailed reports of these studies have already been presented.[2]

In this work individual-tree performance records were kept of the production of several hundred trees by recording the number and weight of the fruits of each grade and size on each tree for periods of from four to eight years. Records were also kept showing the presence of any marked variations of the fruit or foliage of these trees. In many trees of the standard strains limbs were found on which the fruit or foliage was very different from that on the remaining part of the tree, and these differences usually remained constant from year to year. In many instances entire trees were found which possessed similar fruit and foliage characteristics to certain of the limb variations. This condition seemed to indicate that the presence of these diverse strains might be due to the unintentional use of buds from limb variations in the commercial propagation of the trees in these orchards.

The results of these investigations have shown that the population of the citrus orchards which have been studied is made up of a number of diverse strains, some of which are desirable for commercial fruit production while others are detrimental or positively worthless.

PROGENY TESTS OF BUD VARIATIONS

In order to determine whether or not strains may arise as limb variations and be perpetuated through budding, propagations were made in the spring of 1915 of a number of limb sports which were typical of the important established strains, together with propagations of many entire tree variations. The buds secured from these sports were inserted in

[1] Accepted for publication August 18, 1923.

[2] SHAMEL, A. D., SCOTT, L. B., and POMEROY, C. S. CITRUS-FRUIT IMPROVEMENT: A STUDY OF BUD VARIATION IN THE WASHINGTON NAVEL ORANGE. U. S. Dept. Agr. Bul. 623, 146 p., 16 fig., 19 pl. 1918.

——— ——— ——— CITRUS-FRUIT IMPROVEMENT: A STUDY OF BUD VARIATION IN THE VALENCIA ORANGE. U. S. Dept. Agr. Bul. 624, 120 p., 9 fig., 14 pl. 1918.

——— ——— ——— CITRUS-FRUIT IMPROVEMENT; A STUDY OF BUD VARIATION IN THE MARSH GRAPEFRUIT. U. S. Dept. Agr. Bul. 697, 112 p., 14 fig., 11 pl. 1918.

——— ——— ——— CITRUS-FRUIT IMPROVEMENT: A STUDY OF BUD VARIATION IN THE EUREKA LEMON. U. S. Dept. Agr. Bul. 813, 88 p., 22 fig., 7 pl. 1920.

——— ——— ——— CITRUS-FRUIT IMPROVEMENT: A STUDY OF BUD VARIATION IN THE LISBON LEMON. U. S. Dept. Agr. Bul. 815, 70 p., 14 fig., 8 pl. 1920.

sour orange stocks and the trees were grown in cooperation with the Citrus Experiment Station of the University of California. In July, 1917, a part of the progeny trees grown from these propagations were planted on the Station grounds at Riverside, Calif.

The behavior of the progenies as a whole offers most striking and conclusive proof of the value and importance of bud selection in citrus propagation and the wisdom of the methods which have been almost universally adopted in commercial propagation in the Southwest in selecting budwood from uniformly productive and superior parent trees.

THE UNPRODUCTIVE STRAIN OF THE WASHINGTON NAVEL ORANGE

The unproductive strain of the Washington navel orange is one of the most important both from the commercial and scientific standpoints. A typical example of the occurrence of an unproductive limb variation was found in 1910 in a tree grown from a single bud of the Thomson strain of the Washington navel orange in an orchard planted in 1903 near the home of the senior writer at Riverside, and this tree has been under observation each year since its discovery.

This unproductive limb forms the upper part of the main branch of the tree, constituting about one-half of the growth of the tree. It was mentioned on page 25 of the United States Department of Agriculture Bulletin 623,[1] entitled, "Citrus-Fruit Improvement: A Study of Bud Variation in the Washington Navel Orange," and was illustrated in figures 7 and 8 of that publication. Figure 7 is a general view of the tree as it appeared in the summer of 1914, and is reproduced herewith as Plate 1; figure 8 shows the framework structure of the tree with the unproductive limb marked with a handkerchief. The orchard in which this tree stands is favorably located, has been given good cultural care, and the tree has never suffered from frost injury, insect attacks, or fungus diseases. The leaves of the unproductive limb are somewhat different from those of the normal branches, being characteristically smaller, more sharply pointed, more yellowish-green in color, and less abundant. There are no apparent differences in the time of blooming or in the number or structure of the flowers borne by the different branches of the tree.

Detailed performance records of this tree were not secured on account of the fact that it was located at some distance from the Washington navel orange performance-record plats and lack of time and assistance made it impracticable to obtain yield data from it, as was the case with many other interesting isolated trees which have been closely observed for a number of years. The yearly observations of the behavior of this tree both before and after propagations were made from it have shown that the unproductive limb has been consistently unproductive or barren, never having produced more than six fruits in any year until the present season, while the remainder of the tree has borne normal crops. Whenever fruits have been produced on the unproductive limb they have been typical Thomson oranges like those borne by the normal branches of the tree. Some of them have shown minor variations in markings of the rind, as is more or less characteristic of the fruits from the other branches of the tree and of the variety as a whole. For the present season, 1922–23, the normal branches of this tree are bearing approximately 200 fruits, while

[1] SHAMEL, A. D., SCOTT, L. B., and POMEROY, C. S. CITRUS-FRUIT IMPROVEMENT: A STUDY OF BUD VARIATION IN THE WASHINGTON NAVEL ORANGE. U. S. Dept. Agr. Bul. 623, p. 25, fig. 7–8. 1918.

the unproductive portion has but fourteen. Thirteen of these are on one small branch, the foliage of which indicates that it is a reversion to the original Thomson strain.

PROGENY PROPAGATION

Propagations were made in the spring of 1915 from both the unproductive and the normal parts of this tree, budding onto sour orange seedlings of uniform size. Three trees grown from buds from the unproductive limb and two trees grown from buds from a normal branch of the parent tree were planted in a progeny orchard on July 2, 1917. These trees are part of a single row, planted 10 feet apart in the row, the three progeny trees of the unproductive limb being followed by the two progeny trees from the normal part of the same parent tree. Two trees of each progeny are shown in Plate 2.

The orchard in which this progeny is located was planted on land where nothing but winter grain crops had been previously grown. Both winter and summer cover crops have been grown continuously in the orchard since it was planted, but no other fertilizing material has been used. The trees made a vigorous, healthy growth and came into bearing three years after planting.

PROGENY PERFORMANCE RECORDS

The three progeny trees from the unproductive limb have produced a total of five fruits in the three seasons since they came into bearing, while the two progeny trees from the normal branches of the same parent tree have produced a total of 317 oranges, or an average of 53 fruits per tree each year. Table 1 shows the number of fruits produced by these trees each year since they came into bearing. The illustrations of these progeny trees were all taken at the same distance and have been reduced to the same scale in order to show the relative differences in size.

What fruit has been produced by the trees of the unproductive strain has been similar to that borne by the trees of the normal Thomson strain. The progeny trees of the unproductive strain have made a more vigorous growth than have those propagated from the normal branches of the parent tree, as shown in Plate 2, and the two groups of trees show the same foliage differences that characterize the unproductive and normal parent branches.

TABLE I.—*Records of the annual production of progeny trees propagated from an unproductive limb and from a normal branch in a tree grown from a single bud of the Thomson strain of the Washington navel orange*

Season.	Progeny of unproductive limb.			Progeny of normal limb.	
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.
1920 to 1921	1	3	0	18	50
1921 to 1922	0	0	0	61	60
1922 to 1923	0	0	1	56	72
Total	1	3	1	135	182

It has just come to the attention of the writers that besides the five progeny trees mentioned above there are six others close beside them in the same orchard that were propagated in 1914 from this same parent tree by one of the staff of the California Citrus Experiment Station. Three of these were grown from buds from the unproductive part of the tree and three from buds from the normal part of the tree. These progeny trees were planted in 1917 at the same time as those already described and are similar in appearance. These six progeny trees are included in the general variety planting of the experiment station and no production records have been kept of them previous to this year. The three progeny trees grown from the unproductive limb are all absolutely barren this season, while the three grown from the normal part of the parent tree are bearing 58, 65, and 24 fruits respectively, the tree bearing 24 fruits being much smaller than the others.

It is evident that in these cases quantity production has been transmitted by bud propagation from parent limbs to progeny trees, thus demonstrating the possibility of such inheritance. Variations in production are sometimes due to soil or stock influences or to differences in cultural practices. Such variations are of an entirely different nature from those described above and are probably not transmitted in ordinary propagations.

CONCLUSIONS

These results indicate that the number or quantity of fruit produced by citrus trees is a transmittable character capable of perpetuation through bud propagation.

These experiments show how the presence of trees of unproductive strains in established citrus orchards may be due to the unintentional propagation of limb variations of this character.

These facts and the results previously reported emphasize in a most striking manner the great importance of careful bud selection in the commercial propagation of citrus trees in order to avoid the perpetuation of unproductive and worthless strains.

PLATE 1

A tree of the Thomson strain of the Washington navel orange with a large limb variation of the unproductive strain shown at the top and right. Riverside, Calif. Photographed in the spring of 1914.

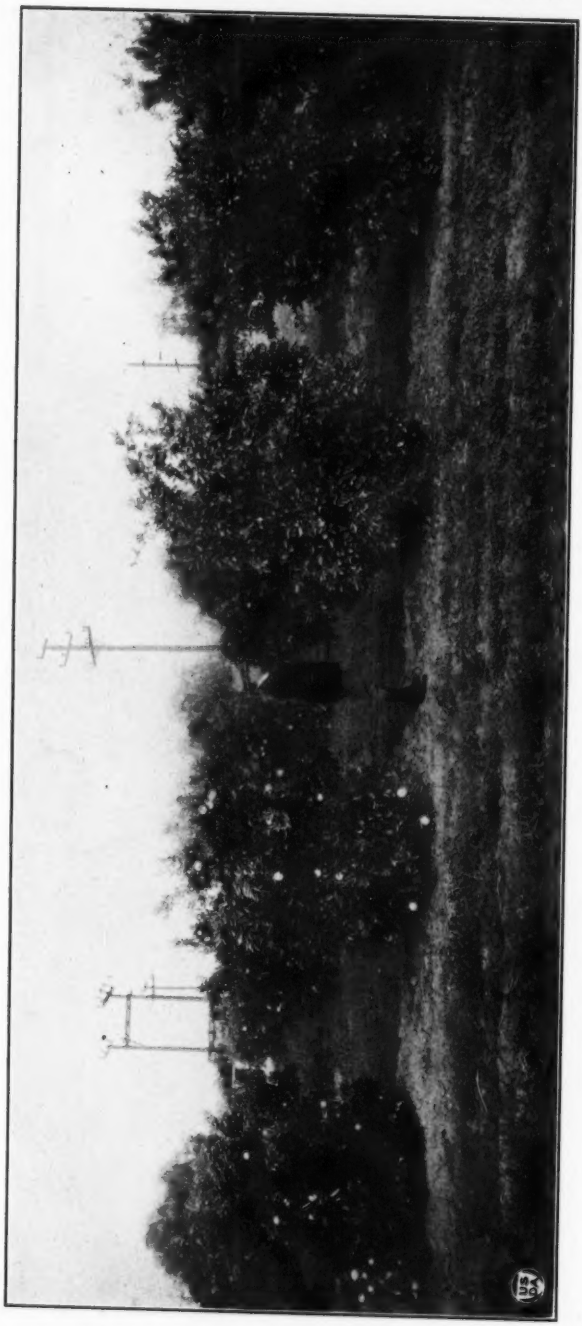

PLATE 2

Two progeny trees, at left, from the normal part of the tree illustrated in Plate 1 and, at the right, two progeny trees from the unproductive limb on the same tree. Citrus Experiment Station, University of California, Riverside, Calif. Photographed December 5, 1922.